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SPRINKLER IRRIGATION OF ORCHARDS IN BRITISH COLUMBIA

J. C. WILCOX
Dominion Experimental Station
Summerland, B.C.

The most popular type of sprinkler system now being installed in British Columbia orchards consists of light, portable pipe held together with specially designed quick couplers. The sprinklers are spaced along the pipe on short risers.

...ed by authority of the RT. HON. JAMES G. GARDINER, Minister of Agriculture, Ottawa, Canada

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FOREWORD

Although sprinkler irrigation has been practised in British Columbia orchards for 15 years or more, it can still be considered in its infancy. From experiment and from experience, a fund of information of considerable value has been built up; however, there is still a great deal to be learned about it. Experimental work is now under way to obtain some of the required information that is lacking.

Fruit growers have been showing a keen interest in sprinkler irrigation, and many of them are replacing their flume-and-furrow systems with sprinkler systems. There has thus developed an insistent demand for information on sprinkler irrigation of orchards. In spite of the fact that the information on this topic is not yet complete, there has been an obvious need for a published outline of such information as is available. This bulletin has been prepared in an attempt to fill this need.

The author has received information and help from sources too numerous to mention individually, and he wishes to express his appreciation for this help. Among the many who have helped are investigators in the States of Washington and Oregon; fruit growers in British Columbia, Washington and Oregon; and equipment dealers in British Columbia. It is desired to make special acknowledgement of editorial and other assistance rendered by the following: Dr. R. C. Palmer, Dominion Experimental Station, Summerland, B.C.; Dr. H. R. McLarty, Dominion Laboratory of Plant Pathology, Summerland, B.C.; G. R. Thorpe, British Columbia District Field Inspector, Creston, B.C.; J. M. Armstrong, Central Experimental Farm, Ottawa, Ont.; Oliver Chemical Company, Penticton, B.C.; Pacific Pipe and Flume Company, Penticton, B.C., and Pumps and Power, Vancouver, B.C.

SPRINKLER IRRIGATION OF ORCHARDS IN BRITISH COLUMBIA

J. C. Wilcox,[1]

Dominion Experimental Station,

Summerland, B.C.

INTRODUCTION

This bulletin deals primarily with the mechanics of sprinkler irrigation of orchards. Its purpose is to help each grower to plan and operate his own system, and to this end there is presented in brief form such information as has been gathered to date on the advantages and disadvantages of sprinkling, on the water supply, on the distribution system, on sprinkler heads, and on sprinkler schedules. For information on the movement, storage and utilization of soil moisture, the reader is referred to Dominion Department of Agriculture Publication 779, "Orchard Irrigation in British Columbia."

The sprinkler method of irrigating orchards has been used in parts of California since early in the century. More recently, it has spread to Oregon, Washington, and several other states in the United States. During the past few years, there have been radical changes in the methods of laying out sprinkler systems, and indeed the whole subject is still in a state of flux. Interest has been keen in the Northwest States. During the war, a lack of materials prevented growers there from installing new sprinkler systems; but since the war ended many of them have made the change from furrow irrigation to sprinkling.

In British Columbia, a considerable fund of information has accumulated on sprinkler irrigation. In one district—Creston—most of the orchards have been sprinkled with undertree sprinklers for 10 years or more. In the Penticton district, a number of scattered orchards have been similarly irrigated for from 10 to 20 years. More recently, sprinkler systems have been installed in a number of other orchard areas in the southern interior of the province. As in the Northwest States, present interest in the subject is keen.

ADVANTAGES AND DISADVANTAGES OF SPRINKLING

The principal method used in the past for irrigating orchards in British Columbia has been the furrow method. In discussing the advantages and disadvantages of the sprinkler method, therefore, it is pertinent to make comparison with the furrow method. The question as to which is the better is of considerable interest at the present time. It seems worth while, therefore, to list the respective advantages and disadvantages of sprinkling in some detail, as they appear from the information now at hand. In the following discussion, only the low undertree type of sprinkler will be considered.

Advantages

1. The most important advantage of sprinkler irrigation is that it causes little or no soil erosion. In hillside orchards, the washing away of the surface soil is frequently a serious matter when water is applied by the furrow method. As the irrigation season progresses, the furrows become deeper and deeper, giving good evidence of soil washing and accompanying loss of organic matter and nutrients (Figure 1). In many such orchards, the original surface soil has now been pretty well all eroded away, and the productivity and value of the land

[1]Assistant in charge of plant nutrition and soil investigations.

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have been markedly reduced. The problem is most serious in silt and sandy soils, especially if they are shallow. Silts and sandy soils usually erode more readily than do clay or gravelly soils. With a shallow soil, of course, the grower can ill afford to lose the all-important top soil. Under sprinkler irrigation erosion can be controlled much more readily than it can under furrow irrigation; in fact, with a combination of sprinkler irrigation and permanent grass sod cover crops, erosion can be almost entirely eliminated.

Figure 1. The deepening of furrows during the irrigation season provides good evidence of soil erosion. In a sandy soil, such as that illustrated here, erosion is usually more serious than in a heavy soil.

2. It is easier to keep the soil properly wetted. This is due primarily to the fact that water is applied over the whole surface area instead of having to spread across between the furrows. The improvement in soil moisture conditions is especially marked with sandy or gravelly soils, in which the lateral spread of water is small compared with its downward movement. It has been common experience that a sandy soil dries out more slowly after a sprinkler irrigation than when the same amount of water has been applied by the furrow method. This is because the soil is wetted more thoroughly by the sprinkler method. As will be noted later in this bulletin, absolute uniformity of wetting cannot be attained even by the sprinkler method.

3. Yields are frequently increased—and sometimes markedly so—by changing to the sprinkler method. This is due primarily to an improvement in soil moisture conditions. The increase in yield is usually more pronounced on sandy soils. On silt and clay soils, the immediate effect on yield may be negligible. If surface erosion is lessened or prevented, however, the ultimate effects on yield can be of the greatest importance.

4. Less water is required. It is true that by the sprinkler method there is greater loss of water by evaporation, which occurs both during the irrigation and afterwards from the surface of the soil. However, water losses by the furrow method are usually much greater, principally through wastage over the

lower ends of the furrows and through loss into the deeper subsoil. These losses are especially serious in light, shallow soils. By the sprinkler method, there should, under proper management, be no loss of water through surface run-off, and very little loss into the subsoil. Experiment and experience indicate that a grower should be able to save 15 to 20 per cent of his water with a heavy soil, and 30 to 50 per cent with a light shallow soil. Putting it another way, if he has not sufficient water to maintain adequate soil moisture by the furrow method, he should with this same water be able to maintain his soil moisture much better by the sprinkler method.

Figure 2. Tailings water from the lower ends of furrows frequently causes serious damage to roadways.

5. There is less trouble to others from run-off and seepage water. By the furrow method, the tailings may cause serious damage to roadways, to vacant lands, or to the neighbour's orchard (Figure 2). Water lost into the subsoil frequently appears farther down the slope as seepage water (Figure 3), drowning out fruit trees or other crop plants. Seepage water also helps to concentrate the alkali in these lower spots. In some districts, run-off and seepage water is helping to break down the cliffs below the orchard lands (Figure 4). With intelligent operation of sprinkler systems, it should be possible to reduce these difficulties to a minimum.

6. Once the distribution system is established, the sprinkler system requires less labour to operate. Some growers claim a saving in time of 50 per cent or greater. Out of a large number of growers questioned on this matter, most of them claimed to have saved considerable time just in the daily routine of moving and watching the water. They attributed this saving chiefly to the fact that when they changed the sprinklers they were able to go about their other work, whereas with furrows they had to stay on the job all day (Figure 5). A part of the saving has been attributed to eliminating the time taken to kill pocket gophers; but this is a questionable saving, as it is advisable to keep the pocket gophers under control anyway. Aside from the time taken in the daily routine, it is

Figure 3. Seepage water emerging from the base of a cliff. In this case, a large section of the hillside collapsed before the spring was brought under control.

Figure 4. Seepage has caused considerable breaking away of the cliffs north of Penticton, on the east side of Okanagan Lake. Some orchard land has already been lost, and much more is threatened.

agreed by all that considerable time and expense are saved in not having to make new furrows each spring, renew them in midsummer, connect them by hand, and keep them opened up by hand throughout the season. As will be

Figure 5. One advantage of sprinklers over furrows is that the former can be left all day while the operator goes about his other work.

noted below, it costs more to lay out a sprinkler system than a furrow system. Experimental evidence indicates, however, that the annual saving in labour by the sprinkler method is frequently more than sufficient to offset the extra costs of depreciation and interest on the system.

7. The absence of furrows makes spraying, hauling, and other orchard operations easier to perform. Some growers claim a considerable saving in wear and tear on orchard machinery, while others stress the saving accompanying less bruising of the fruit in hauling. It is difficult to place any exact monetary value on these savings.

8. It is easier to start and maintain cover crops. In starting a cover crop, two difficulties are encountered by the furrow method. In the first place, it is hard to keep the soil properly wetted at or near the surface. The young plants may start out well in the spring, then later on die between the furrows because of lack of water. This effect is especially marked with such shallow-rooted crops as white Dutch clover and fescue. Another difficulty is that when the irrigation furrows are made in the spring, the soil that is thrown out covers up the young cover crop plants on either side of the furrow and may kill them out (Figure 6). Not only does sprinkler irrigation make it easier to start a cover crop, but it makes it possible to plant it at any time during the spring or summer. Even after the cover crop is well established, it can usually be maintained more easily by the sprinkler method, due primarily to improved moisture conditions close to the soil surface. The benefits of sprinkler irrigation are more apparent with shallow-rooted crops like white Dutch clover, ladino clover and creeping red fescue. Another advantage is that the cover crop is easier to mow where there are no furrows present, and it can thus be kept low enough not to interfere with spraying and other orchard operations.

Figure 6. It is difficult to start cover crops under the furrow method, especially where they are fine-seeded. One difficulty is that when the furrows are made, the loose earth covers up the young plants and kills them out adjacent to the furrows.

9. It is easier to control or cure alkali in the soil. In the case of black alkali, gypsum (applied as a cure) can be washed down into the soil more quickly and uniformly; and in the case of white alkali the harmful mineral salts can be washed down into the subsoil more easily.

10. It is not necessary to level rolling land prior to planting. Levelling is undesirable not only because of the expense but also because of the exposure of infertile subsoil. In such exposed areas, it is often very difficult to obtain high production even with heavy fertilization.

11. The sprinkler system can be used as a means of applying fertilizers, and some growers in Washington and Oregon are now applying them in this manner. It is still questionable, however, whether anything is to be gained by using this method of fertilizer application in orchards.

Disadvantages

1. One of the chief disadvantages is the higher initial cost of a sprinkler system, in comparison with a flume or ditch system. At present prices, it will cost $100 to $150 per acre for the materials and equipment (not including pump and power) necessary for a portable pipe system of sprinklers. This is much higher, as a rule, than is necessary for a system of flumes; and where it is necessary to develop pressure with a pump, the initial cost of the system will be still higher. Possible exceptions to the general rule are orchards on land that is cut up by gulleys or is irregular in contour, so that fluming would be difficult to install. The costs will be discussed more fully later in this bulletin.

2. It is necessary to maintain the water under pressure. This means either that each Irrigation District as a whole must carry the water under pressure in pipes, or the grower must develop the pressure himself. Either method adds to the expense. Where it is necessary to pump to obtain pressure, there is the added expense of fuel or electricity.

3. It is necessary to have relatively clean water. Where the water is not clean enough to start with, it must be adequately screened. Sprinkler nozzles become plugged with trash more readily than do flume gates.

4. Wetting of the leaves and fruit by sprinklers may cause damage by washing off the spray or by maintaining more humid conditions and thus encouraging diseases and insect pests. This possibility is not so serious with undertree sprinklers as with overtree sprinklers. The disease and insect problem will be discussed more fully below.

5. Water scattered by sprinklers can be blown aside by heavy winds. This problem is usually not serious with low undertree sprinklers that have a low trajectory.

6. The cover crop is wet when the sprinklers are being moved. This means wet feet for the operator unless he wears waterproof boots. If there is no cover crop, the ground will be muddy. However, it is inadvisable to operate sprinklers without a good cover crop.

7. Sprinkling is best adapted to a continuous supply of water. This is chiefly because part-time operation increases the number of sprinklers and portable pipes required, and thereby increases the cost of installation. In some Irrigation Districts, water is not now supplied to the growers on a continuous basis. Furthermore, many growers with small orchards have come to prefer discontinuous irrigation.

Wetting of Leaves and Fruit

The possibility of aggravating the disease and insect problem by sprinkling deserves serious consideration. At the present time, there is not sufficient information available on its application to British Columbia orchards.

The pros and cons of the evidence available can be summarized as follows:

Pro:

1. Undertree sprinklers of a type that wet the lower leaves and fruit have been used for 10 to 20 years in the Creston and Penticton districts, and as far as the information available is concerned they have had little if any deleterious effect on the fruit. In 1945, a number of such orchards in the Penticton district were examined for diseases. The trees grown included apples, pears, cherries, apricots, and peaches. In all orchards, the butterfly type of sprinkler was used, and in some cases the leaves and fruit were wetted during irrigation to a height of eight feet or more. In spite of this, no more disease was found in the sprinkled orchards than in nearby furrow-irrigated orchards. A possible explanation is that the sprinklers were usually not operated for longer than 12 hours in any one place.

2. High overtree sprinklers are being used in a number of orchards in the State of Washington, and the growers using them claim to be obtaining good results, such as less mite injury and better fruit colour, together with no visible washing off of the spray.

3. Experimental work in the State of Washington has indicated that overtree sprinkling can help in controlling red spider, powdery mildew on the fruit, and possibly Pacific mite.

Con:

1. In experimental work in the State of Washington, overtree sprinkling has been found to aggravate powdery mildew on the leaves, perennial canker rot on the fruit, pear blight, and downy mildew rot on pear and peach fruits. In addition, sprinkling washed some of the arsenic sprays and some of the copper sprays off the leaves and fruit. This was true also of the lower portions of some of the trees where undertee sprinklers were used.

2. Individual growers in Washington, Oregon and British Columbia have encountered some difficulty from downy mildew rot of peaches or pears, from powdery mildew, from apple scab, from early dropping of pear fruits, and from sunscald on the leaves and fruits, where the trees have been wetted by sprinkling. Some of the growers concerned were located in Western Oregon and Western Washington, where comparatively humid conditions are encountered. In no case reported has the grower considered his problem serious enough to induce him to return to furrow irrigation.

As already noted, this evidence is incomplete. It is just possible that wetting of the leaves and fruit might induce more mildew, scab, or other diseases in more humid districts; or that new sprays might be used that can be washed off more readily; or that new pests which might appear in British Columbia orchards would be aggravated by wetting of the leaves and fruit.

Figure 7. To be on the safe side, it appears advisable to use a sprinkler with a low trajectory.

On the whole, it appears that until more is known about the possible effects of wetting of the leaves and fruit, every effort should be made to sprinkle in such a manner as to wet them as little as possible. This means using undertree sprinklers rather than overtree sprinklers, placing the sprinklers on as low stands as feasible for adequate water distribution, placing them in the centres of the tree squares where they will be least likely to

wet the fruit and foliage, using a sprinkler head with a reasonably low trajectory (Figures 7 and 8), and using a water pressure no higher than necessary for adequate water distribution.

General Recommendations

1. It is recommended that wherever serious difficulties are encountered by the furrow method of orchard irrigation, the grower should give consideration to the use of sprinklers.

2. Sprinkler irrigation is recommended (a) when the orchard is planted on a hillside, because of the danger from erosion by the furrow method (Figure 9); (b) on light, shallow soils, in order to save water and prevent leaching (Figure 10); (c) on rolling or irregular contours, where furrow irrigation is difficult to handle (Figure 11); (d) where white alkali has collected, as this can be washed out more readily by sprinkling. In cases such as this, the possible disadvantages of the sprinkler method appear to be more than offset by the known disadvantages of the furrow method.

Figure 8. Sprinklers with a high trajectory have been commonly used in British Columbia orchards in the past, and they appear to have given reasonably good service. However, water distribution is not as satisfactory as with a low trajectory, and there is more danger from certain insects and diseases.

3. Installation of sprinkler irrigation may also be justified in many orchards where conditions are reasonably favourable for irrigation by the furrow method. In such cases growers should give careful consideration to the advantages and disadvantages of the two methods as presented above. They should also take note of the precaution mentioned below.

4. Wherever new irrigation systems are being installed on a district basis, every effort should be made to deliver water to the growers under pressure, so that each grower may, if he wishes, use the sprinkler method without having to develop pressure.

Figure 9. Sprinkler irrigation is recommended for those side-hill orchards that are subject to soil erosion when irrigated by the furrow method.

Figure 10. Sprinkler irrigation is recommended for sandy or gravelly soils. There are plenty of orchards in British Columbia planted on gravel piles like this.

Figure 11. Sprinkler irrigation is recommended for land that is rolling or irregular in contour, such that it would be difficult to irrigate by the furrow method.

5. In the light of present knowledge of the subject, overtree sprinklers are not being recommended. Even with undertree sprinklers, it appears advisable to use them in such a manner as to wet as little of the foliage and fruit as possible.

It is recognized that many growers who should be using the sprinkler method are not able to finance the installation of the system. It is also recognized that many growers have recently installed permanent and highly expensive flume systems. This, however, does not invalidate the general recommendations outlined above.

THE WATER SUPPLY

Quality of Water

Whether for sprinkler irrigation or for furrow irrigation, the water used should be of good quality. More especially, it should not contain too much black alkali or white alkali. On a heavy soil, a little alkali can cause a lot of harm within a few years' time. On a light soil with good drainage, a small content of alkali in the water will not be as dangerous. Nor is it as dangerous when the water is applied by the sprinkler method, as the grower then has better control over the soil moisture and can leach out the excess minerals when necessary. Even so, it is asking for trouble when irrigation water is used that contains alkali.

Almost all of the water now used for irrigation in the Okanagan Valley has been tested for alkali, and most of it has been found quite satisfactory. Occasionally, however, samples of water are obtained that are too high in alkali. These are usually from ponds, lakes or creeks that have been produced in part or in whole by seepage water (Figure 12). Before a grower uses any new source of water for irrigation purposes, he should have it tested for alkali. It might even be advisable to have the tests repeated every few years. This is especially true with small lakes, ponds, or drainage ditches, where changes in alkali content may occur from year to year. These tests are made free of charge at the Dominion Experimental Station at Summerland, B.C.

Figure 12. Small lakes or ponds are frequently used as sources of irrigation water. Before using them, the grower is well advised to have the water tested for alkali.

Although clean water is desirable, it is not essential, as it can be screened before use. Methods of screening will be discussed below.

Amount of Water

Sufficient experimental work has not yet been done on this phase of the problem in British Columbia to justify making specific recommendations. The evidence at hand indicates that a somewhat lesser quantity of water should

prove satisfactory for sprinkler irrigation than is needed for furrow irrigation. The saving that can be anticipated from using sprinklers will depend largely on the type of soil. As already noted, the saving may be only 15 to 20 per cent with a deep heavy soil, but as high as 50 per cent with a light shallow soil.

Factors other than the soil also effect the amount of water required. More water is needed when the trees are larger or are planted closer together. More water is needed for a cover crop than for clean cultivation. And more water is needed in those districts with a hot, dry climate than in those with a cool, moist climate.

It may be several years before definite recommendations regarding the water requirements for sprinkler irrigation can be made for each district. In the meantime, the evidence at hand indicates that for a deep heavy soil the season's requirements might safely vary from 18 inches in the Salmon Arm area to 30 inches in the Osoyoos area, and for a light shallow soil from 24 inches to 42 inches in these respective areas. There are of course gravel piles that may require even more water than this. These figures are suggested on the assumption that the water is applied with reasonable intelligence. Although it is much easier to maintain proper soil moisture with a minimum of water by the sprinkler method than by the furrow method, flagrant cases of the misuse of sprinklers have been encountered.

Not only is the total amount of water that is required important, but so also is the delivery capacity of the irrigation system. During the heat of the summer, more water is required than during the cooler periods. The capacity must of course be designed to meet the greatest demand for water. For most soils, a delivery capacity of 5 Imperial gallons per minute (g.p.m.) per acre appears satisfactory. This is equivalent to 9·5 acre inches per month. With deep silt or clay soils, it may safely be reduced to 4 g.p.m., but with light, shallow soils 6 g.p.m. or even more may be desirable. It should be noted that the 4, 5 or 6 g.p.m. per acre suggested is not applied to each acre separately throughout the season. As will be noted later, it is customary to concentrate the water on one part of the orchard for a time, for a short time only, then to move it on to another part.

The above figures are based on continuous flow of water. If the flow is only part time, the delivery capacity of the system would have to be stepped up accordingly. Where a grower has a private source of water, he may have a choice of continuous flow or part-time flow. If his orchard is quite small, he may prefer the part-time flow but this will of course involve a greater expense in setting up the system. Where he receives his water from an Irrigation District, he may not always be able to receive a continuous flow, in which case he will be placed at a disadvantage in that the cost of his sprinkler system will be increased.

Developing Pressure

It is necessary that the water be delivered to the sprinklers under pressure. All of the low-type sprinklers that have been tested here and have been found satisfactory for orchard use will operate at pressures as low as 10 pounds or even less. However, they have not been found to distribute the water uniformly enough except at pressures of 15 pounds or higher. In most cases, pressures of 20 to 30 pounds have proved the best. Tests of uniformity of water distribution from sprinklers operating at pressures of 10 to 60 pounds will be reported later in this bulletin.

The pressures noted above are those at the sprinkler. As the water flows through the delivery pipes to the sprinkler, its pressure is reduced somewhat by friction, thus necessitating a still higher pressure at the pipe intake. An

exception to this is where the delivery pipe slopes downhill sufficiently to overcome the loss of pressure from friction. Methods of calculating losses from friction will be discussed below under "The Distribution System."

Some growers are able to develop sufficient pressure by gravity. They obtain their water at some point above their orchard, and pipe it down hill to the point of use. The pressure obtained in such a case can be calculated by dividing the height in feet by 2·31 and deducting the frictional losses. For efficient use of most sprinklers, it is therefore necessary to have the pipe intake at least 40 to 50 feet above the highest sprinklers.

Whenever water enters a pipe from an open box or flume, there is bound to be a certain amount of air enter with it. In order to minimize this difficulty, it is advisable to have the water reasonably still at the intake. Water that is flowing fast or is in turmoil has considerable air mixed with it. In addition, it is advisable to erect a standpipe from the main pipe below the intake, with an air-release valve on top of it. Air vents might also be placed at one or more high points along the main delivery pipe, whether the water comes from an open intake or is pumped from a lake, river or well.

It sometimes happens that the owner of a hillside orchard cannot develop sufficient pressure by gravity for his highest trees, but can do so for most of his orchard. What some growers do in such a case is to irrigate the top two or three rows of trees by the furrow method, and the balance of the orchard by the sprinkler method. Other growers prefer to use the sprinklers throughout, even though the top ones operate at very low pressures. When their soil is sandy, they feel that they obtain better water distribution in the soil by poor sprinkling than they would by the use of furrows.

If pressure cannot be developed by gravity, it will have to be developed by pumping. This will of course add to the expense, both of installation and of annual operation. The best type and size of pump to use will depend on the flow of water, the height of lift (if any), the slope of the orchard, and other factors. As a guide to available pumps and power requirements Table 7 has been appended, showing the capacity of various sized piston and ejecto pressure systems operating on a tank pressure of 40 pounds, and the capacity of various sized piston and centrifugal pumps operating on heads of from 20 to 231 feet or 8·7 to 100 pounds pressure. Commercial pump firms are in a position to assist growers in choice of equipment. Whenever such a firm is approached for advice, it is of course necessary for the grower to supply information concerning the required capacity, lift, pressure, etc.

Some growers have to pump their water up from a point below the orchard. In such a case, the extra power required to develop 15 or 20 pounds pressure in the sprinklers usually adds comparatively little to the initial expense or to the operating cost when compared with furrow irrigation. There may be some difficulty, however, if a grower who now pumps for furrow irrigation changes to sprinkler irrigation with no change in his pump or motor. Neither the pump nor the motor may be suitable for the additional pressure required. The necessary adjustments may be only slight, especially if less water is needed by the sprinkler method. However, the grower should obtain competent advice on his pump and motor, whether he is installing a new system or is changing over from furrow irrigation to sprinkler irrigation.

Screening the Water

For efficient use of sprinklers, it is necessary to have the water clean enough that the sprinklers will not plug up. One of the chief advantages of the use of sprinklers is that the operator can start them off in the morning and then go about his other work. But if the water is dirty and the sprinklers plug, he must be on hand to clean them and the advantage is lost.

In some areas, clean water is delivered to the growers by their Irrigation Districts. These Districts either have sources of comparatively clean water —such as a lake—or they have gone to considerable expense to filter it. The grower who has clean water delivered to his orchard can consider himself fortunate.

In most of the Irrigation Districts, the water as now delivered to the growers cannot be considered suitable for sprinkler use. It contains both sand and floating organic matter. When the grower decides to use it for sprinkling, therefore, it is usually his own individual responsibility to remove the sand and floating matter first.

Water is sometimes delivered to the grower in an open flume, sometimes in a pipe under pressure. In the former case, settling and screening are accomplished together in a "screening box." The size of the box, the number of screens, and the screen mesh required will depend on the flow of water and on its content of sand and floating debris. General plans for screening boxes are suggested in Figures 13, 14 and 15, suitable for orchards of 20 to 30 acres and for water containing only a fair amount of floating matter. Each of these types has been used by growers and has been reported by them to be satisfactory. The dimensions given are of course approximations only, and would need to be varied to meet individual needs. Various other types are also being used successfully by growers.

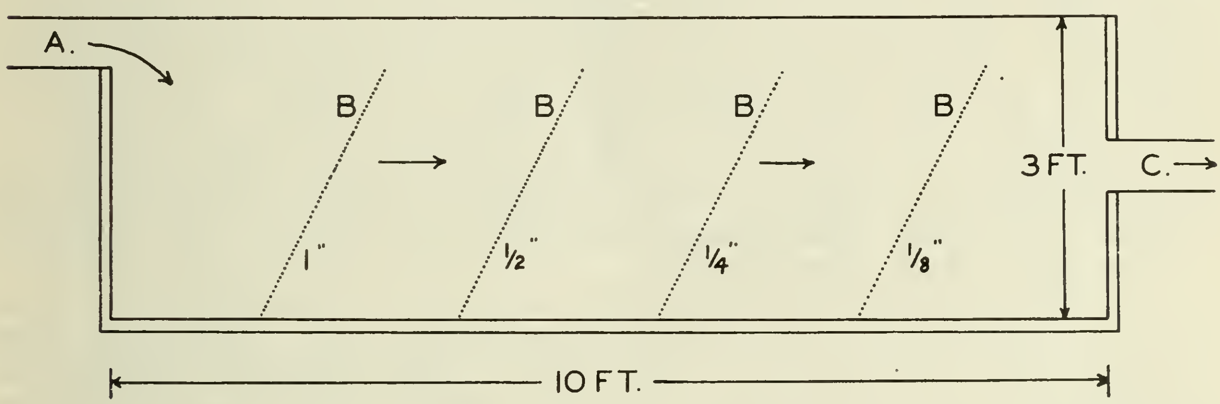

Figure 13. A screening box 3 x 3 x 10 feet, with four screens ranging in mesh from 1 inch to ⅛ inch. If a screen plugs up, the water can flow over it without overflowing from the box. The screens fit into grooves, and can be pulled out for cleaning. A—inlet. B—screens. C—outlet.

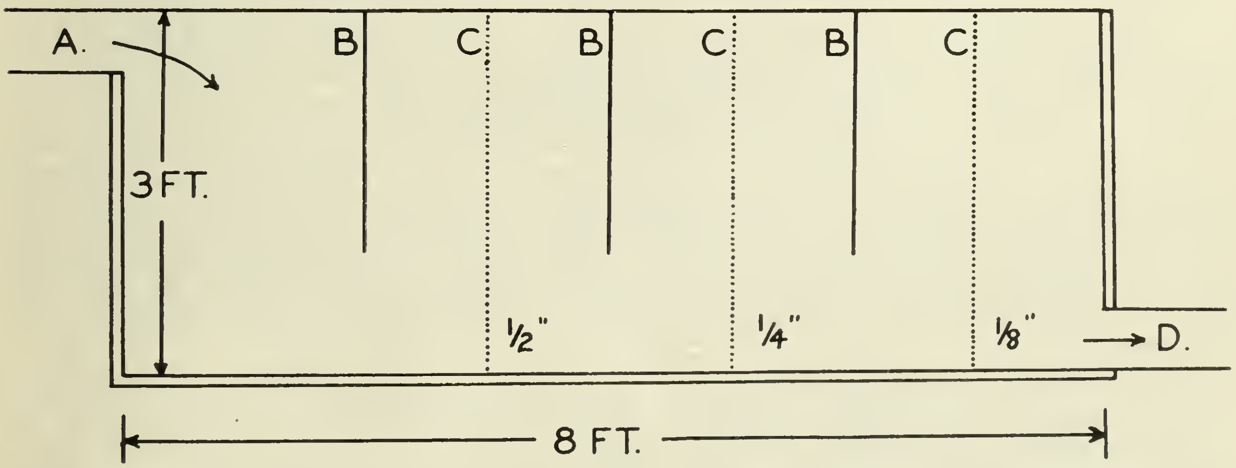

Figure 14. A screening box 3 x 3 x 8 feet, with three screens ranging in mesh from ½ to ⅛ inch. The water is slowed up by baffles, thus allowing better settling out of sand. The screens are pulled out for cleaning. A—inlet. B—baffles. C—screens. D—outlet.

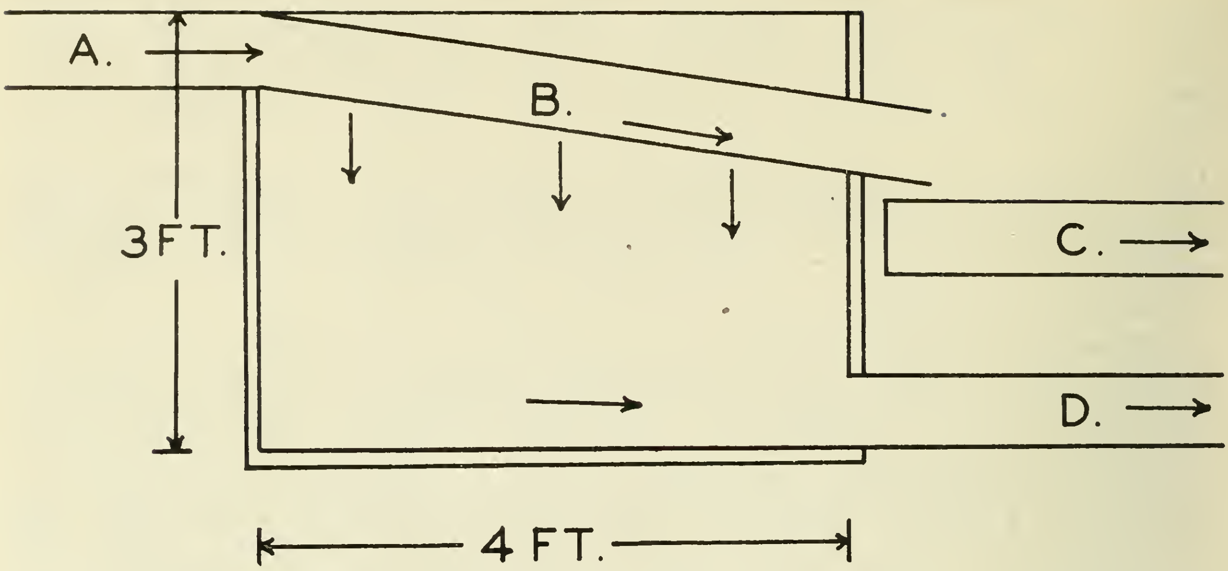

Figure 15. A screening box 2 x 3 x 4 feet. The water falls through a fine screen, so arranged that a little water passes over it and thus keeps it cleaned off. A—inlet. B—adjustable flume with bottom of fine screening. C—flume to carry off excess water. D—main outlet.

All three of the boxes illustrated are open at the top; and in all three the water enters at the upper left and leaves at the right. The box illustrated in Figure 13 is higher than the screens, so that if a screen plugs right up the water can flow over it without washing out of the box. The screens suggested are 1 inch, $\frac{1}{2}$ inch, $\frac{1}{4}$ inch and $\frac{1}{8}$ inch, respectively, from left to right. Extra space is allowed at the left of the first screen for settling out of sand and gravel.

In Figure 14 the screens occupy the complete cross section of the box. Between each set of screens is a baffle, to help slow up the water and thus allow settling of the sand. With either of these first two types of box, additional screens can be used where necessary.

In Figure 15, the water is carried across the top of the box in a wide flume (B), that empties beyond the box into a second flume (C). The bottom of the first flume (B) consists of fine copper screening, which allows the water to fall through into the box. The flume is sloped downward in such a manner that just a little water passes over the end, and this keeps the screen cleaned reasonably well. The size and slope of the flume can be adjusted to suit. The water lost over the end of the screen can be used for furrow irrigation at the top of the orchard. Growers using this type of box claim that it needs almost no attention.

The screening of water under pressure is a somewhat more difficult job. Fortunately, water delivered in pipe is seldom as dirty as water delivered in flumes or ditches. Two types of screening tanks that have been successfully used by growers are illustrated in Figures 16 and 17. In Figure 16, the screen is attached to the lid in such a manner that it can easily be separated from it for cleaning. In Figure 17, the screen is flat, and must fit tightly in a groove at the top, bottom and sides of the tank. Other types of screening tanks are being used by growers. Tanks that can be cleaned without removing the lid are now being manufactured by sprinkler agencies. They show good promise for general use.

Although it is advisable to clean the water carefully at the orchard intake, it may sometimes be worth while to screen it under pressure on the line or at each sprinkler. Line filters are available, as are small screens that fit into the base of the sprinkler riser or just below the sprinkler head. If trouble is encountered with plugging of the sprinklers, these small screens are worth trying.

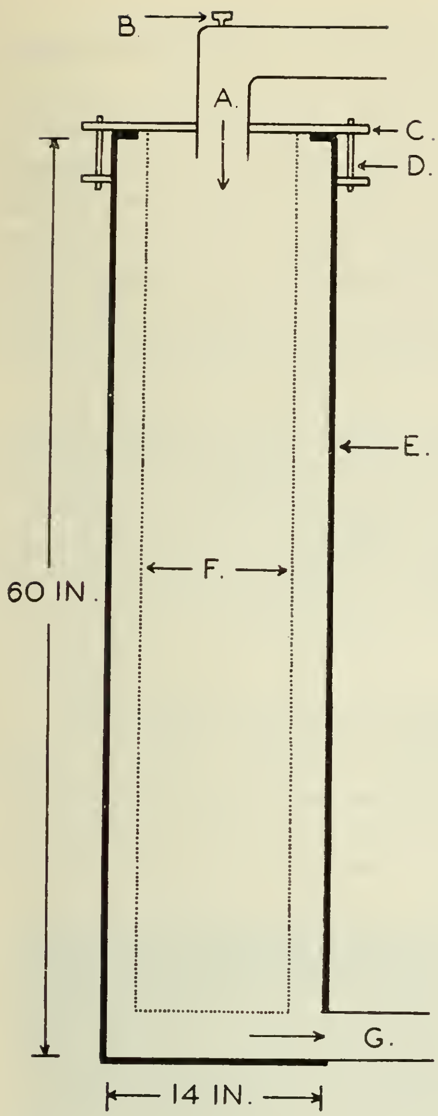

Figure 16. A screening tank used for cleaning water under pressure. It is made from a second-hand kitchen boiler and ⅛ inch galvanized screening. A—inlet. B—air outlet valve. C—heavy iron lid with gasket. D—bolts for holding lid on. E—tank. F—screen, in the shape of a cylinder open at the top. G—outlet.

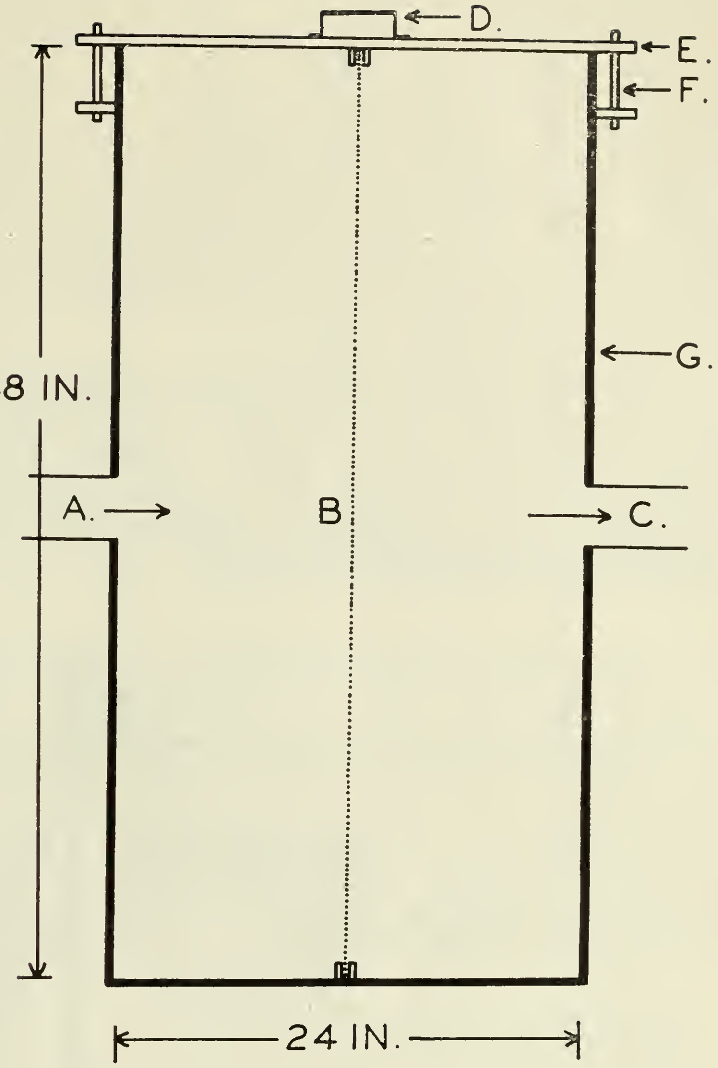

Figure 17. A screening drum for cleaning water under pressure. An oil drum is used, with one end replaced by a heavy lid. A single ⅛ inch screen is placed across the drum from end to end. A—inlet. B—screen. C—outlet. D—handle on lid. E—heavy lid. F—bolts to hold lid on. G—drum.

THE DISTRIBUTION SYSTEM

Permanent Systems

A permanent system has no portable parts. As a rule, the only labour required for operation is to turn one or two valves off and on each day.

Permanent systems are seldom used in orchards. When they are used, they usually consist of an underground main pipe through the centre of the orchard, an underground lateral pipe down the centre of each panel, and a riser topped by a sprinkler head in the centre of each tree square. Such a system lends itself to very low labour operational costs. The cost of installation, however, is much too high for most growers to afford. Besides, a permanent standpipe in the centre of each tree square constitutes a nuisance in the orchard as it interferes with orchard operations.

Portable Hose Systems

A so-called "portable hose" system consists primarily of permanent underground pipes and portable hoses and sprinklers.

The delivery pipe usually consists of a main pipe 3 to 6 inches in diameter, running through the centre or along one side of the orchard. Most growers have been using iron pipe, coated inside and out with asphaltum or similar product. One common source of 4-inch or smaller pipe has been second-hand boiler-tubing. The pipe lengths are usually welded right on the spot, before sinking them in the ground. Other materials than iron have occasionally been used, and apparently with good satisfaction. Among such materials are wood stave and reinforced concrete.

The size of pipe required depends on the initial pressure, the length of pipe, the flow of water, and the final pressure required at the sprinklers. When the flow of water that will be needed is known, a rough approximation of the loss of pressure from friction can be calculated from Table 1 in the Appendix. Examples of the calculation of frictional losses will be given at the end of this section on the distribution system.

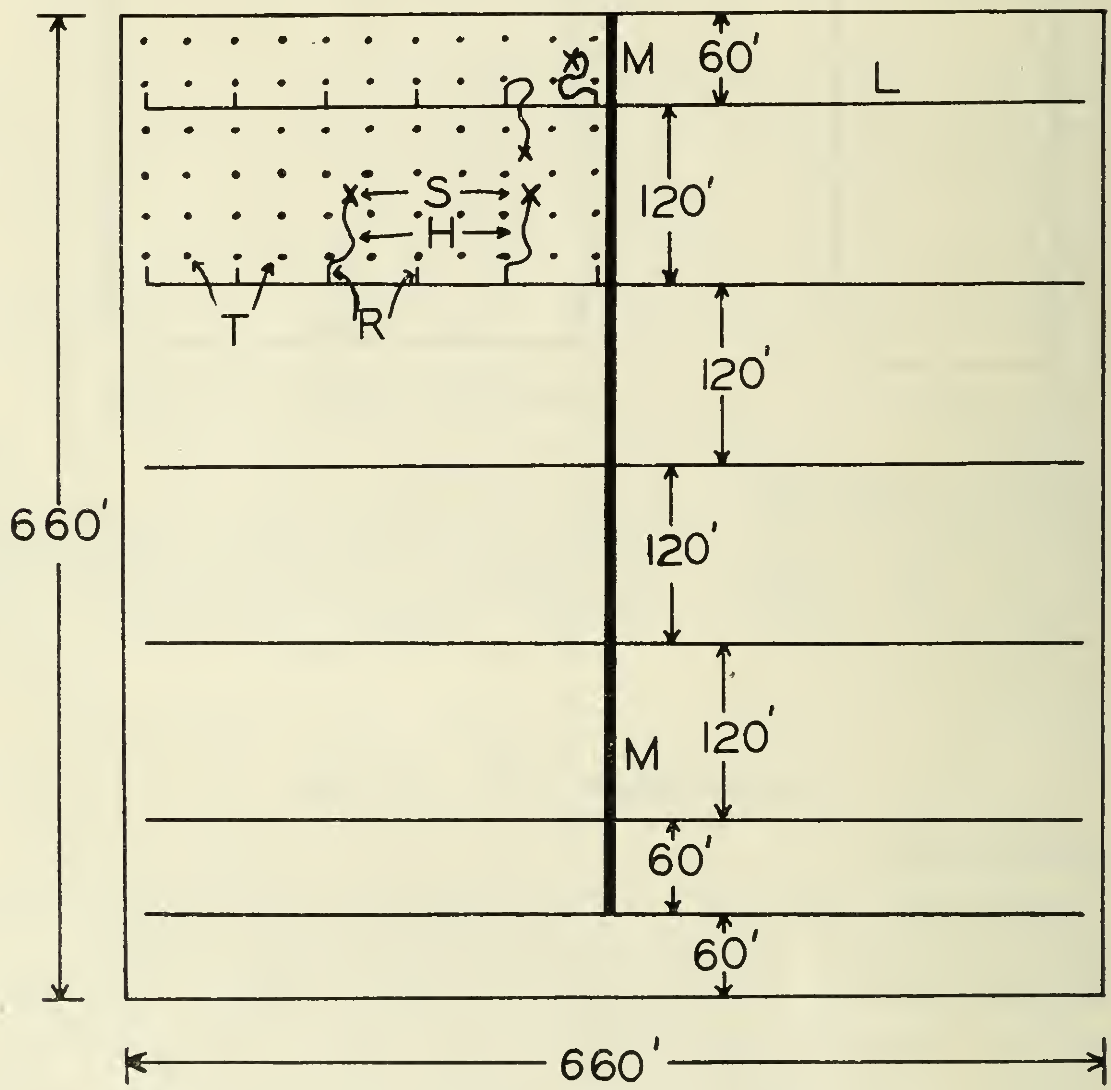

Figure 18. Diagram of a portable hose system in a square 10-acre orchard. The trees are 30 x 30 feet apart, and the laterals 120 feet apart. T—trees. M—main line down centre of orchard. L—lateral lines. R—sublaterals, from lateral to near a tree trunk. H—hoses. S—sprinklers.

The depth to which the delivery pipe needs to be sunk will depend on whether it is to be used throughout the year for delivery of domestic water. If so, it will need to be low enough to obviate danger from frost. If not, it only needs to be low enough to be out of the way of tillage implements. The same holds true with the lateral pipes. All pipes that are not sunk deeply should of course be drained as soon as the irrigation season is finished. To facilitate this, the pipes should all be on steady slopes; or failing this, drainage taps or stop-and-wastes should be installed at all low spots. Where there is a danger of silt settling out in low spots, the outlets should be large enough to facilitate washing the silt out.

At regular distances along the main delivery pipe, smaller lateral pipes are attached at right angles. This is illustrated in Figure 18. The size of pipe required will depend on the initial pressure and on the flow of water in each lateral. It usually ranges between one and two inches. Some growers reduce the size of pipe toward the outer end. Since it is customary to run not more than five sprinklers on any one lateral at once, these smaller-sized pipes have proved quite satisfactory. Lateral pipes are usually joined with threaded couplings.

The lateral pipes are usually spaced at distances of 90 to 120 feet apart. With distances less than this, the cost becomes too high, while with greater distances, the hose is too long to drag around easily. Where the orchard area is irregular in shape, the laterals will of course have to be placed to suit the convenience of the operator. In any case, each lateral should be placed well away from the trunks of the trees. This will save cutting too many roots when it is sunk in the ground or if it ever has to be dug up again.

Figure 19. Standpipes for hoses should be placed near tree trunks, where they will not interfere with orchard operations.

Standpipes are placed at regular distances along each lateral. A suitable distance is at every second tree row. Each standpipe can be placed directly above the lateral, or—better still—near the trunk of an adjacent tree (Figure 19). In this latter position, they should not interfere with cultivating, hauling, or other orchard operations. They can be connected with the lateral by short sub-laterals. Each standpipe is usually made of $\frac{1}{2}$-inch or $\frac{3}{4}$-inch pipe, and is topped by a cheap tap or valve with a male hose takeoff.

The hoses need to be about half as long as the laterals are spaced apart. In most orchards a heavy $\frac{3}{4}$-inch hose is advisable; though if the water pressure is high, a $\frac{1}{2}$-inch hose may prove adequate. For the most part, a single sprinkler is placed at the end of each hose. In some cases, however, growers have spaced two or three sprinklers along each hose, at the same distance apart as the tree spacing (Figure 20). This method reduces the number of hoses required, but increases the frictional losses. Whether one or more sprinklers are used on one hose, each sprinkler should be placed in the middle of a tree square while in use.

A wide variety of sprinkler stands are in common use. Where the soil is comparatively light but not stony, a spike-type of stand (Figure 20) often proves satisfactory. It is not suitable, however, when a hammer-action type of sprinkler is used, as the jarring tends to knock the stand sideways. More commonly, broad-based metal or wooden stands are used, sometimes purchased but more frequently home made (Figures 21, 22). Metal stands are often supplemented with wood, to give them a broader base. A suitable height for the sprinklers is usually 12 to 18 inches above the ground.

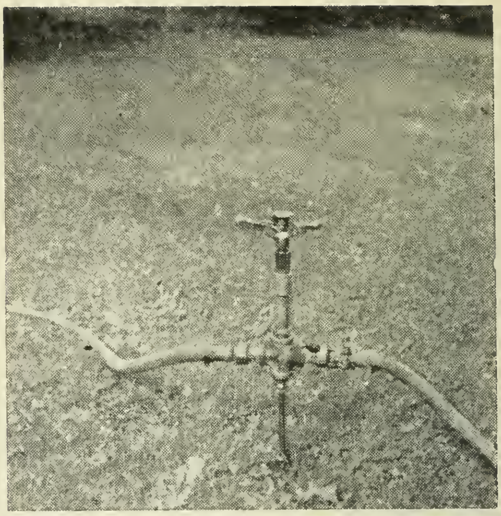

Figure 20. If so desired, one or more sprinklers can be inserted in the hose line. Shown above is a Rainbird 20LA sprinkler on a home-made spike stand.

As will be noted from the price comparisons later in this bulletin, it costs more at present prices to install a portable hose system than a portable pipe system. Moreover, hoses wear out faster than do pipes. The portable hose system, therefore, does not look so promising for general use as does the portable pipe system.

Figure 21. A Browning 50 sprinkler on a stand of unknown manufacture. The stand pulls along the ground readily with the hose.

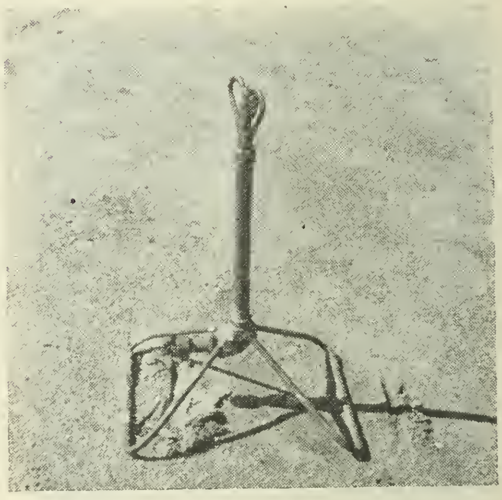

Figure 22. A butterfly sprinkler on a home-made stand.

There are certain possible exceptions to the above statement. One place where the portable hose system shows special promise is in orchards that are cut up by gulleys or are irregular in outline or contour. Under such conditions the portable pipe system would be difficult to handle. The portable hose system is the more flexible of the two.

The portable hose system also shows some promise where the grower is using a stationary spray plant. He will then have a system of spray pipes already functioning in his orchard, and it may be possible to combine the two systems. A difficulty encountered, however, has been that the pipe used for delivering the spray needs to be small enough to ensure rapid movement of the

liquid and thus prevent settling out, and this pipe is almost certain to be too small for delivery of the irrigation water. This difficulty may not arise if the irrigation water can be delivered under a sufficiently high pressure. As a rule, however, it appears necessary to use two sets of main pipes, each of which can be connected by a series of valves to the one set of lateral pipes. With a small main pipe for the spray, a large main pipe for the irrigation water, and a suitable system of valves, spraying and irrigation can proceed at the same time in different parts of the orchard. It is doubtful, however, if the pumps used for spraying could be adapted to deliver the larger volume of water required for irrigation. In any case, new types of spray machines now on the market appear to have lessened the popularity of stationary spray plants in British Columbia.

Portable Pipe Systems

A "portable pipe" system as used in British Columbia consists primarily of a permanent main pipe through the middle or down one side of the orchard, and smaller portable pipes that replace both the permanent laterals and the hoses of the portable hose system. Risers and sprinklers are attached directly to the portable pipe or its couplers. A popular type of portable pipe system is illustrated in Figure 23.

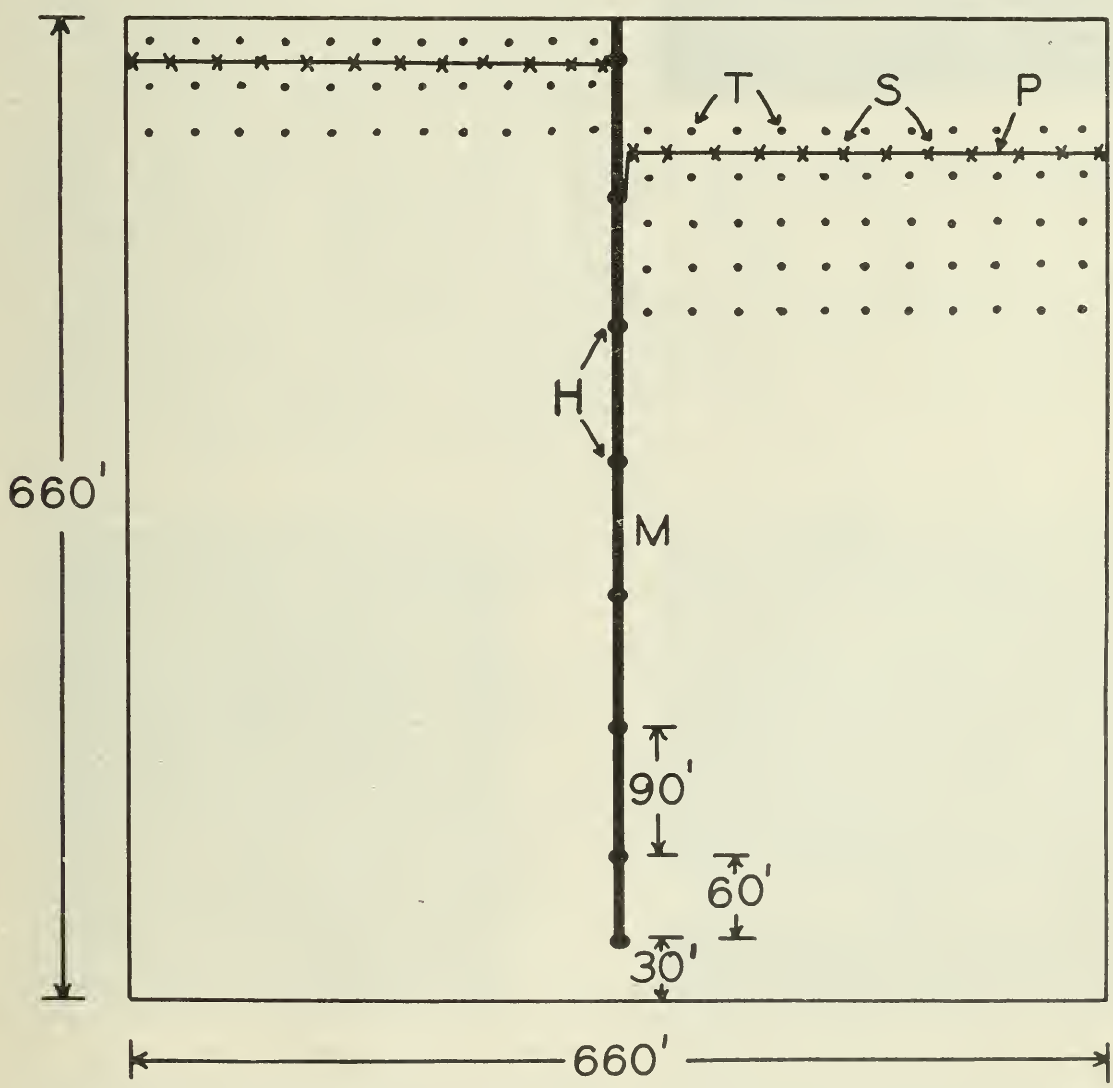

Figure 23. Diagram of a portable pipe system in a square 10-acre orchard. The trees are 30 x 30 feet apart, and the hydrants 90 feet apart along the main. T—trees. M—main line down the centre of the orchard. H—hydrants. P—portable lateral line. S—sprinklers.

In some types of farming it has been found convenient to use portable pipes only and no permanent pipes. In such a case, the whole system is truly "portable". In orchards, however, the main delivery pipe is usually permanent. When placed in the middle of the orchard, it should be sunk underground; but when placed along one side of the orchard it may be feasible to leave it on the surface, especially if it is well out of the way of the path of orchard equipment. Leaving it on the surface lessens the cost of installation, and facilitates draining and cleaning of the pipes. The discussion above on the main delivery pipe of a portable hose system applies equally well here.

Figure 24. A home-made hydrant. It contains a 2-inch valve and can be turned in any direction. It attaches directly to a Wade-Rain coupler.

When the permanent pipe is placed underground, it is necessary to use some type of hydrant for delivering the water up to the portable lateral. Such a hydrant should contain a good valve. If the portable pipes are to be run on either side of the main pipe, then each hydrant must either have a double outlet or be capable of turning to face different directions. Whether home-made or purchased, a good hydrant is expensive, but well worth the cost (Figure 24). Suitable hydrants may be obtained from any portable-pipe dealer.

Because of the high cost of good hydrants, it has become customary to place one at every third position of the portable pipe (as in Figure 23), instead of at every position. An extra length or two of portable pipe is then used parallel with the main pipe to make the necessary connections. These extra lengths may be connected directly to the hydrant by a portable coupler. In some cases, however, it has been found more convenient to use a length of heavy hose between the pipe and the hydrant. Some growers have placed their hydrants at every fifth position; but when the saving in cost of hydrants is balanced against the extra cost of portable pipe and the additional inconvenience, it is doubtful if they are gaining anything in comparison with a hydrant at every third position.

When the main pipe is laid on the surface of the ground, the connections can be somewhat simpler and cheaper, especially if the portable pipes are to be used in the one direction only. It is still necessary, however, to have a good valve at each outlet from the main pipe.

When water is being turned from the main line into a lateral line of portable pipes, it may be advisable to open the valve only sufficiently to produce a certain stated pressure in the portable line. As a guide to help in regulating the pressure, a small pressure gauge can be placed on the first length of portable pipe, close enough to the main line to be readily seen when the water is being turned on.

Portable pipe is manufactured from some light material such as aluminum, light galvanized tubing or light steel. Each of these types has its advantages. Aluminum is the lightest and easiest to handle. It does not rust. It is corroded by alkali, and should therefore not be laid in direct contact with alkaline soil; but this need not cause much concern in most British Columbia orchards. In the past, it has been somewhat more expensive than the other two types. Galvanized tubing is somewhat heavier than aluminum. It is ordinarily "non-rustable", but when the galvanized coating is in contact with the soil for any length of time it may corrode and render the pipe "rustable". Light steel pipe is usually coated before use with asphaltum or similar material. This keeps the pipe from rusting for a while, but it tends to flake off with use. The pipe is somewhat heavier than aluminum. Its biggest advantage is its initial low cost.

The best diameter of pipe to use depends on the frictional loss in pressure that can safely be allowed. The diameter of pipe usually used in orchards is 2 inches, which is quite satisfactory for the frictional losses normally encountered. Where the lateral lines are especially long, or where sprinklers of high capacity are used, a 3-inch pipe may occasionally be found necessary. Examples of the calculation of frictional losses will be given at the end of this section.

Portable pipe has in the past been supplied almost entirely in 20-foot lengths. Some firms are now supplying it in other lengths as well; and with some firms it can be obtained in other lengths on special order. The most suitable length depends on a number of factors, chief of which is the spacing of the trees. This will be discussed further in connection with sprinkler spacing.

The individual lengths of portable pipe are held together by short couplers, so constructed that coupling and uncoupling can be accomplished quickly and easily. Each coupler is fitted with a pliable rubber gasket or ring, that expands under water pressure and effects a seal. At the present time, only four such couplers are being used to any extent by orchardists in British Columbia: (1) *Stout coupler* (Figure 25). Made of aluminum. Pipes can be coupled or uncoupled by the operator while he stands at the centre of each length. If so desired, a lever on the coupler can be used to hold each pipe and standpipe upright, but this necessitates raising the lever every time a length is moved. This coupler allows a good angle of divergence between lengths. (2) *Wade-Rain coupler* (Figure 26). Made of galvanized iron. Pipes can be joined by shoving from the centre of each length, but they must be manually uncoupled. The coupler allows a good angle of divergence between lengths. The Wade-Rain is also sold in British Columbia as the "Redirain". (3) *Calco coupler* (Figure 27). Made of galvanized iron. Is coupled with a lever, which makes a tight seal for both water and air. It is necessary to couple and uncouple at the coupler. The tight seal holds the pipes upright, as long as any one of them is held upright in some way. This coupler is not quite so flexible as the first two noted. (4) *Pierce coupler* (Figure 28). Made of light steel or aluminum. Coupling and uncoupling can be accomplished from the centre of each length of pipe. The coupler allows a good angle of divergence between lengths. It costs somewhat less than the other couplers. The Stout, Wade-Rain and Calco couplers have outlets for risers, but the Pierce does not.

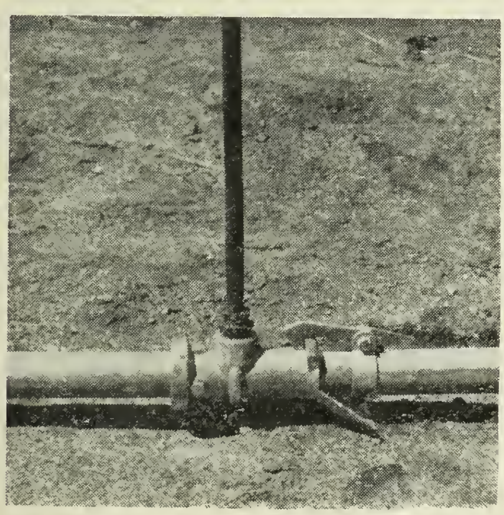

Figure 25. A Stout coupler, showing riser attached to it. The coupler itself is attached firmly to one pipe.

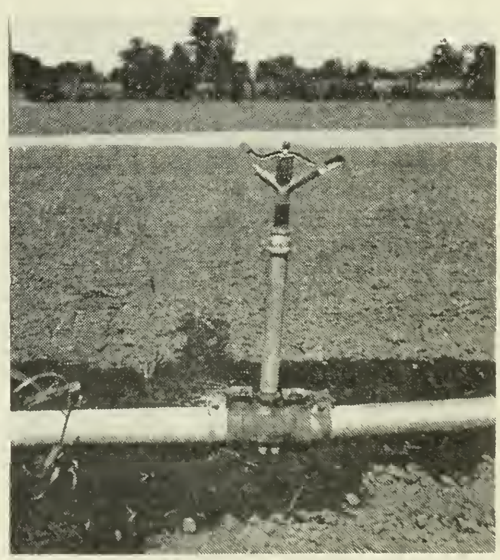

Figure 26. A Wade-Rain coupler, showing riser attached to it. The coupler is readily detachable from both lengths of pipe. The sprinkler shown is a Rainbird 40.

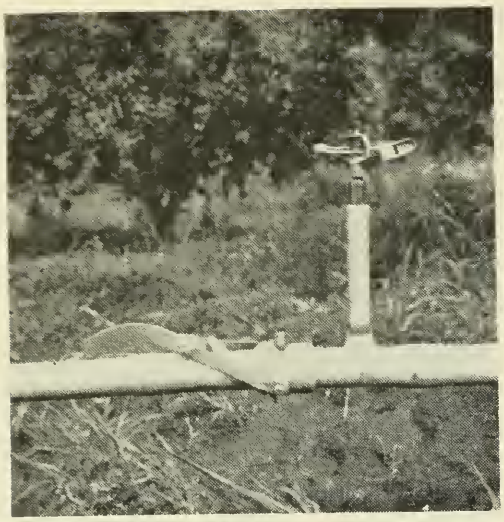

Figure 27. A Calco coupler, with riser attached to adjacent pipe. The coupler itself is attached to one length of pipe. The sprinkler shown is a Rainbird 20LA.

Figure 28. A Pierce coupler attached to short lengths of light steel pipe. In use, the coupler is welded to the portable pipe.

The customary spacing of the sprinklers has in the past depended primarily on the length of each portable pipe. This is due to the fact that riser outlets are usually placed in the couplers. Because the pipes as sold have been 20 feet long, therefore, the sprinklers have usually been spaced 20 feet apart in orchards. This is not always the best spacing. In many cases, it is advisable to space the sprinklers along the portable pipe in such a manner that each sprinkler is located in the centre of a tree square. This can be accomplished in one of two ways,—either by obtaining portable pipes of the same length as the tree spacing, or by using 20-foot lengths and making riser outlets along the pipe wherever necessary.

In most orchards, it is desirable that the sprinkler risers be at right angles to the ground surface. A slanting riser will cause poor distribution of the water from the sprinkler; and it may also cause excessive wetting of the trees on one side of the lateral line. This latter situation is sometimes obtained when the orchard is on a side-hill and the risers are placed vertically instead of at right angles to the slope. One difficulty with risers that are not vertical is that a single-armed sprinkler may turn more rapidly as it turns downhill than as it turns uphill, thus giving unequal distribution of water on the two sides. At pressures of 20 pounds or greater, this difficulty is usually not serious. In any event, this disadvantage is usually not so serious as those caused by not having the risers at right angles to the slope.

Various methods are used to hold the risers at the desired angle. One method is to hold the first pipe length solidly in the desired position—such as by attaching it firmly to the hydrant—and attaching each succeeding pipe to it with a non-flexible coupler. Another method is to flatten out the base of the coupler itself. On rough ground, this alone does not always prove satisfactory. It is frequently necessary to attach a board to the base of the coupler, or to use some other device for keeping the risers in position.

On sloping or irregular ground, it is frequently difficult to maintain a uniform pressure along a lateral line. One of the simplest ways of regulating the pressure from sprinkler to sprinkler is to place a cheap valve in each riser. The valves can then be adjusted to give about the same distance of water throw from each sprinkler. In this way, reasonable uniformity in the rate of application of water can be obtained.

The best height to have the sprinklers above the ground depends on a number of factors, including the height of the cover crop, the kind of sprinkler

head, and the water pressure. Under orchard conditions, it is preferable to adapt the cover crop to the sprinklers instead of the reverse. This can be accomplished either by growing a low type of cover crop or by mowing it during the summer. If the pressure is higher than required, it can be reduced to the point where the spray is being thrown no higher than necessary; but if the pressure is too low it may be advisable to increase the length of the risers somewhat. Where a sprinkler tends to throw the water upward in an arc, it should be placed as close to the ground as feasible; but where it throws with a flat trajectory, it may need to be placed somewhat higher. As a rule, heights of 12 to 18 inches above the ground have given good satisfaction.

On hilly ground, the question arises as to whether it is better to run a lateral line uphill or downhill. Where it is run uphill, the sprinklers at the bottom of the hill (near the main line) throw more water than do those at the top. The effect is sometimes great enough to produce adequate wetting at the bottom in one-third or one-quarter the time required at the top. The best way of counteracting such an effect is as has already been suggested, to place a valve in each riser.

Where the lateral lines run downhill, the effect on the pressure depends on the slope. If the slope is only slight, the effect may be to produce a more uniform pressure throughout the whole length of the lateral. In so far as each lateral is concerned, such a set-up is highly desirable. More frequently, however, the slope is steep enough to produce a much greater pressure at the bottom (farthest from the main) than at the top. Again, the best way of correcting for this is to insert a valve in each riser. Another way is to insert one or more valves along the lateral line, and to close them down until all of the sprinklers are throwing about the same distance. The net effect by either method is to increase the flow of water in the top sprinklers and reduce the flow in the bottom sprinklers, thus making the distribution more uniform throughout.

Sometimes a grower has a choice as to which direction his main line will run through the orchard. Where the orchard is on a side-hill, either the main line or the laterals may be run on the level. If the laterals are on the level or slope downhill slightly, the pressure will be reasonably uniform at any one placing of a lateral. A difficulty arises, however, in that the pressure increases in the main all the way down the slope, so that much more water is applied at the bottom part of the orchard than at the top. This difficulty can be obviated to some extent by placing a valve at the outlet from the main and cutting off the flow of water at the lower levels until the pressure in the lateral is the same as that obtained at the higher levels. This will of course limit the pressure to a uniformly low figure. If this pressure is high enough for adequate distribution, the method should prove quite satisfactory. If it is not high enough, the better procedure would seem to be to run the main line along the level side and to place a valve in each riser to control the pressure.

The total length of portable pipe required per acre depends on the number of sprinklers required and their distance apart along the laterals. The number of sprinklers, in turn, depends on the flow of water required per acre and the rate of water delivery by each sprinkler. As a general rule, a capacity of about 5 Imperial gallons per minute per acre is needed, although it may vary somewhat below this for deep heavy soils and somewhat above it for shallowy sandy soils. If the sprinkler used delivers 2 gallons per minute at the pressure used, this would mean about 2½ sprinklers per acre for most orchards. On this basis, a spacing of 20 feet along the lateral would mean a requirement of about 50 feet of portable pipe per acre; and a spacing of 30 feet would mean about 75 feet of portable pipe per acre. This will be discussed again later. In the meantime, it should be noted that when 2½ sprinklers and 50 feet of portable pipe are specified per acre, this does not mean that these items are used separately on each acre.

As already noted, they are connected together into one or more lateral lines of portable pipe. Each lateral is used in a single panel for a short time only, and is then moved on to the next panel.

Lateral lines of varying length are used in orchards. For the most part, they range between 200 and 400 feet in length. It frequently happens that a grower has a choice of placing his main line along one side of his orchard and using one long lateral, or of placing it down the centre and using two shorter laterals. With the long laterals, the frictional losses will be greater. The total reduction in pressure is nearly half as great again in one line of 400 feet as it is in two lines of 200 feet. Another disadvantage of the long single lateral is the extra difficulty of disposing of the water while the line is being moved; not to mention the extra wastage of water. The most desirable length of line will of course depend to a large extent on the size and shape of the orchard. With some of the larger orchards, lateral lines longer than 400 feet may be not only feasible but desirable.

Where two or more lateral lines are required, the question arises as to where they should be situated and how they should be moved. If the main line runs down the centre of the orchard, and a lateral line is run on either side of it, it is customary to start them close together at one end of the orchard and move them toward the other end. An exception to this is where the orchard is on a slope and the water is pumped up from below. To keep the pump under a more uniform load, it may be advisable to start one lateral line at the top of the orchard and one at the bottom. If two laterals are needed on one side of the main, they can be moved from either end toward the centre and then back again. It is not convenient, as a rule, to run two laterals adjacent to one another on the same side of the main, because of having to carry each length twice as far when making a change.

The procedure commonly used in moving a lateral line of portable pipes is as follows: (1) Turn off the water at the hydrant. Do this slowly, so as not to produce a hammer knock in the main pipe. (2) Disconnect the pipe or hose at the hydrant, move the hydrant connection, and if necessary move the length of portable pipe that runs parallel with the main pipe into its new position. Successive placings of the lateral line are usually in adjacent tree panels; but with close plantings they may be two panels apart. (3) Disconnect the first length of the lateral line (nearest the main line), carry it to its next position, and connect it again. (4) Open valve at new position a little, to wash dirt out of pipes. (5) Carry and connect each successive length of pipe, making sure that the sprinklers are all in their proper position and that the risers are set perpendicular to the ground. (6) Turn on the water full again at the hydrant. This also should be done slowly. The time taken to move a given length of pipe varies with the operator, the distance the pipe is being moved, the type of coupler, the type of cover crop, etc. It usually takes one man about 45 minutes to move a lateral line 400 feet long.

One of the principal weaknesses encountered in the portable pipe method of irrigating is that while the pipes are being moved they are not delivering their share of the water. Some special means must therefore be found for looking after the water not being used at this time. When the grower has his own private source of supply, the problem is much easier to handle; he can close the water off at its source, or stop his pump, or just let his pump deliver into his other lateral lines, and no harm done. But where he receives a certain flow of

water from his Irrigation District, and is responsible for this flow, the problem is more difficult to handle. If the extra water is not used in some way, it needs to be flumed or piped to where it can do no damage. One way of handling it is to divert it into some irrigation furrows saved for this purpose. Another way is to have one more lateral line than would otherwise be necessary, and to turn the water off one line and into another line at the same time. With a small orchard, this might double the total length of portable pipe required, but with a larger orchard the increase would not be so great in proportion. A further advantage of this method is that the operator can be changing a line of portable pipes while waiting for the scheduled time to change the water. For larger orchards, therefore, the extra expense involved in purchasing an extra line of portable pipes may well be worth while.

In spite of its weaknesses, the portable pipe type of system shows the greatest promise at the present time for general use in the sprinkler irrigation of orchards. At present prices, it is cheaper to install than the portable hose type of system.

Calculation of Frictional Losses

Losses in pressure due to friction are tabulated in Table 1 in the Appendix. The figures shown refer to the loss in pounds of pressure per 100 feet of rusted or pitted iron pipe.

There is a great deal of variability in the frictional losses in iron pipe, depending partly on the type of pipe and partly on how seriously it has been roughened inside. With usage, the inside walls of the pipe may become badly rusted, which will cause a considerable increase in friction. The losses are less in new iron pipe, but it is safer in installing a sprinkler system to allow for an increase in frictional losses with use. From this standpoint, the figures in Table 1 can be considered reasonably safe.

Portable pipes are usually made of aluminum or galvanized tubing; or if made of light steel they are usually coated with asphaltum. The increase in frictional losses with age is therefore less than with black iron pipe. To calculate the approximate loss of pressure from friction in such pipe, the figure in Table 1 can be multiplied by $\frac{2}{3}$. Another factor that must be taken into account with portable pipes is the reduction in flow of water as it passes each successive sprinkler. Because of this reduced flow, the total loss from friction is less. A reasonably close approximation of the pressure lost in getting to the farthest sprinkler can be obtained by multiplying the loss of pressure that there would have been without any sprinklers by $\frac{2}{5}$. Multiplying $\frac{2}{3}$ by $\frac{2}{5}$ gives 0·27; accordingly, if the respective figure in Figure 1 is multiplied by 0·3, this should give a conservative estimate of the frictional loss in a portable pipe with sprinklers spaced along it.

Frictional losses in rubber hose are also very variable. Where definite information is not available on the frictional characteristics of the hose in use, the figures in Table 1 can be used as a reasonably safe guide in making calculations of losses.

Once the frictional losses have been calculated, there still remains to calculate the gain or loss in pounds of pressure due to differences in elevation. To determine this figure, the difference in elevation in feet is divided by 2·31. Thus a rise of 2·31 feet in the pipe, in the direction of water flow, reduces the pressure by 1 pound, and a fall of 2·31 feet raises the pressure by 1 pound. The figure thus obtained needs to be added to, or subtracted from, the frictional loss.

In so far as pressure alone is concerned, it is the greatest reduction in pressure that is the most important. If the sprinkler representing the greatest reduction in pressure (i.e. the sprinkler receiving the lowest pressure) has sufficient pressure for good distribution of water, then the pressure should be adequate over the whole system. This sprinkler may be the farthest one away from the pump or intake, or it may be the highest one in elevation. The lateral or the portable pipe on which this sprinkler is placed is the only one that needs to receive consideration in calculating pressure losses. The other laterals or lines of portable pipe can be ignored.

To illustrate the method of calculating pressure losses, consider the following examples:

1. A 10-acre orchard with a portable hose system, as in Figure 18. There is a 4-inch main pipe, 610 feet long; each lateral is $1\frac{1}{2}$ inches in diameter and 300 feet long; the sublaterals are 1 inch in diameter and 10 feet long; and the hoses are $\frac{3}{4}$ inch and 50 feet long. One sprinkler is to be placed on each hose. The total rate of water flow is to be 50 g.p.m., with 25 sprinklers delivering 2 g.p.m. each. Not more than 6 sprinklers are to be run on any one lateral at once. The system is powered by a pump at the edge of the orchard. The land is practically level.

The total flow of water in any one lateral will not be more than $6 \times 2 = 12$ g.p.m. At this flow, the water will gradually be removed by successive sprinklers, and the frictional loss can be multiplied by $\frac{2}{5}$ as with a portable system. The flow in each sublateral and hose will be 2 g.p.m. The water will not all flow all the length of the main pipe at any one time. The greatest average length of full flow will probably be about 500 ft. On this basis, the greatest frictional loss can be calculated as follows:

50 g.p.m. in 500 feet of 4-inch pipe	
Loss $= \dfrac{500}{100} \times 0 \cdot 2 = 5 \cdot 00 \times 0 \cdot 2 =$	1·0 pound
12 g.p.m. in 300 feet of $1\frac{1}{2}$-inch pipe, with sprinklers spaced along it.	
Loss $= 3 \cdot 00 \times 1 \cdot 2 \times 0 \cdot 4 =$	1·5 pound
2 g.p.m. in 10 feet of 1-inch pipe (Can be ignored)	
2 g.p.m. in 50 feet of $\frac{3}{4}$-inch hose	
Loss $= 0 \cdot 50 \times 1 \cdot 1 =$	0·6 pound
Total loss $=$	3·1 pounds

To determine the net pressure, 3·1 would be deducted from the pressure at the pump. On this basis, the net pressure should preferably be between 20 and 30 pounds, and the pressure at the pump at least 3·1 pounds higher than this.

In this example as in the three to follow, small sources of friction loss, such as standpipes, taps, couplers, elbows, valves, etc., have been ignored. To be on the safe side, another pound or two should be added to the total pressure loss as calculated here. This safety factor should in no case be less than 10 per cent. In this case, adding 10 per cent would make the total loss equal to 3·4 pounds, but it would be safer to count on 4·0 pounds. In other words, the pressure at the pump would need to be least $20+4 = 24$ pounds, and prefer-

ably higher. This refers to the delivery pressure of the pump. There will also need to be calculated the frictional losses and head to be overcome in sucking the water up to the pump.

2. A similar set-up to No. 1, except that the water is delivered to the edge of the orchard through a 3-inch pipe 300 feet long, with its intake 100 feet above the orchard. The main pipe is reduced to 3 inches, the lateral pipes to 1 inch, and the hoses to half inch.

50 g.p.m. in 300+500 = 800 feet of 3-inch pipe.	
Loss = 8·00=0·7 =	5·6 pounds
12 g.p.m. in 300 feet of 1-inch pipe, with sprinklers spaced along it.	
Loss = 3·00×10·0×0·4 =	12·0 pounds
2 g.p.m. in 50 feet of ½-inch hose	
Loss = 0·50×4·5 =	2·3 pounds
Total loss =	19·9 pounds
Safety factor =	2·0 pounds
	21·9 pounds

The pressure gained by difference in elevation=100/2·31=43·2 pounds. The net pressure at the farthest sprinkler, therefore, would be about 43·2—21·9=21·3 pounds.

3. A 10-acre orchard with a portable pipe system, as in Figure 23. There is a 3-inch main pipe down one side of the orchard, 630 feet long, and one 2-inch galvanized portable lateral pipe 660 feet long. The flow is 40 g.p.m., and power is supplied by a pump at the corner of the orchard. Between the pump and the farthest corner of the orchard, there is a drop in elevation of 15 feet.

40 g.p.m. in 630 feet of 3-inch pipe	
Loss = 6·30×0·5 =	3·2 pounds
40 g.p.m. in 660 feet of 2-inch pipe, with sprinklers spaced along it.	
Loss = 6·60×3·4×0·3 =	6·8 pounds
Total loss =	10·0 pounds
Plus safety factor of 1 pound =	11·0 pounds
Gain in pressure from elevation =15/2·31 =	6·5 pounds
Net loss =	4·5 pounds

On this basis, the pressure at the pump would need to be at least 25 pounds.

4. A 10-acre orchard with a portable pipe system. Water is pumped from a lake up a hill to the orchard, through a 300-foot, 4-inch pipe, that continues for a further 630 feet through the centre of the orchard. The pump is not used full time, and the total flow is 80 g.p.m. The greatest elevation is 150 feet above the pump, and is at the back of the orchard, farthest from the pump. There are two 2-inch portable laterals, each 330 feet long. Each will handle 40 g.p.m. Since the orchard slopes steeply toward the lake, the load on the pump is equalized by starting one lateral at one end of the orchard and one at the other end. By this procedure, the average distance of the two laterals

from the lower edge of the orchard is always approximately one half the length of the orchard. In calculating the frictional loss in the main pipe, it is therefore necessary to count only half of the 630 feet, or 315 feet.

80 g.p.m. in $300+315=615$ feet of 4-inch pipe	
Loss $= 6{\cdot}15 \times 0{\cdot}5 =$	3·1 pounds
40 g.p.m. in 330 feet of 2-inch aluminum lateral, with sprinklers spaced along it	
Loss $= 3{\cdot}30 \times 3{\cdot}4 \times 0{\cdot}3 =$	3·4 pounds
Total frictional loss $=$	6·5 pounds
Plus safety factor of 2 pounds $=$	8·5 pounds
Loss in pressure from elevation $= 150/2{\cdot}31 =$	65·0 pounds
Total loss in pressure $=$	73·5 pounds

On this basis, the pressure at the pump would need to be at least 94 pounds.

THE SPRINKLER

Desirable Characteristics of an Undertree Sprinkler

The sprinkler is the most important part of the whole system. Only in so far as the sprinkler works efficiently can the system be considered to work efficiently. The purpose of all the rest of the equipment is to service the sprinkler and to help it to perform as it should.

It is highly important that the sprinkler used should be suitable for undertree sprinkling, and especially adapted to low pressure use. The desirable characteristics of such a sprinkler can be summarized as follows:

(1) It should throw with a low trajectory. This is based on the arguments already presented under "Wetting of Leaves and Fruit."

(2) It should distribute the water reasonably uniformly, when overlapping has been taken into consideration.

(3) It should work well at a wide range of low pressures—for example, from 10 to 30 pounds.

(4) It should be adjustable for a reasonably good range of nozzle sizes.

(5) It should be adjustable for distance of throw, so that it can be adapted to different distances of planting. This might be accomplished by changes in nozzle size, in pressure, or in height of trajectory.

(6) It should turn slowly. This reduces wear, and allows the sprinklers to be moved or cleaned without wetting the operator.

(7) It should not plug too easily with floating debris, and it should be capable of easy cleaning when plugged.

(8) It should be reasonable in price. This need not be stressed too much, however, as the sprinklers are not only the most important part, but also almost the cheapest part, of the whole system.

No one sprinkler is perfect. For example, no sprinkler of those tested thus far at the Experimental Station at Summerland has distributed water uniformly at pressures of 10 pounds or less.

Delivery Capacity

The rate of water delivery by a sprinkler depends on the size of nozzle, the style of nozzle, and the pressure at the nozzle. For the most part, the sprinklers in common use have nozzles that allow unobstructed discharge of

the water. Based on unobstructed discharge, the rates of delivery by different sized nozzles at different pressures are tabulated in Table 2 in the Appendix. The rates shown in this table are for single nozzles only. They would need to be doubled for double nozzles. Under actual operation, different sprinklers vary somewhat in their delivery capacity, even with the same listed nozzle size and at the same pressure. This can be attributed largely to differences in machining and in sprinkler head construction.

The rate of water delivery by a sprinkler can be used as a basis for calculating the average depth of water application at each sprinkler spacing. The average depths for a number of different spacings are tabulated in Table 3 in the Appendix. It should be noted that where an average depth of application is shown, it does not mean that this depth of water is applied uniformly over the whole area specified. In some cases there is likely to be much more water in one part of the area than in another part. This is especially true with the wider spacings.

The most desirable rate of water delivery depends on the amount of water to be applied, the length of each irrigation, the spacing, and the type of soil. A slow rate of delivery is desirable when the rate of application per hour is small, where the area covered is small, and where the soil is heavy. A clay soil will not absorb all of the water when it is applied rapidly. As a general rule, a nozzle size of $\frac{1}{8}$-inch or smaller should be used with clay soils. With light shallow soils, a small nozzle may also be desirable; otherwise, the operator may have to change his sprinklers too frequently. On the other hand, if he can adapt his schedule to frequent moving of the sprinklers, he can save on costs of installation by using sprinklers with a high delivery capacity. Nozzle sizes will be discussed again below.

When the desirable rate of water delivery by a sprinkler has been determined, the question arises as to which is preferable, two small nozzles or one large nozzle. The double nozzle sprinkler usually turns somewhat more steadily when the riser is slanted. On the other hand, the single nozzle—being larger—does not plug so readily with dirt. Where there is dirt in the water, therefore, the single nozzle usually gives better performance than does the double nozzle.

In order to assist in making calculations in connection with rate of water delivery, the relation between the total rate of water flow per acre and the depth of application per month is tabulated in Table 4 in the Appendix.

Uniformity of Water Distribution

One of the main advantages of the sprinkler method is greater uniformity of water distribution, as compared with furrow irrigation. However, the water *can* be—and frequently is—distributed very unevenly in actual sprinkling of orchards. One reason for this is a poor combination of pressure, nozzle size, and sprinkler spacing. Other reasons include tree interference with the distribution of water and blowing aside of the spray by wind.

In order to determine the uniformity of water distribution by different types of sprinkler, tests were conducted at the Dominion Experimental Station at Summerland in 1946. Only those sprinklers were tested that were on sale in 1946 in British Columbia for undertree use. Where different sized nozzles were available, they were compared. Tests were made of each sprinkler at pressures of 10, 15, 20, 30, 45 and 60 pounds. All tests were run when there was little or no wind. In each test, the sprinkler was run for one hour, and the distribution of water was measured with tin cans laid out around the sprinkler in a regular pattern (Figure 29). Calculations were then made of the depth of water in each can, with overlapping from adjoining sprinklers taken into account. This was done for sprinkler spacings of 20 x 20, 25 x 25, 30 x 30, 40 x 40, 20 x 30, 20 x 40, 20 x 50, and 20 x 60 feet. From the figures thus obtained was calculated the "uniformity coefficient" for each sprinkler at each pressure and at each

spacing. A uniformity coefficient of 100 would indicate perfect uniformity of distribution within the space under consideration, and coefficients below 100 would represent proportionately poorer uniformity.[2]

Figure 29. In order to test the uniformity of water distribution by sprinklers, cans were spaced in a 5 x 5 foot pattern and the sprinklers were placed in the centre and run for one hour. A Buckner sprinkler is shown in operation.

Of the sprinklers tested, those that showed the greatest promise for undertree use were as follows:

(1) *Rainbird 20LA,* with a 7° nozzle (Figures 20, 27). This sprinkler turns slowly, with a hammer action. It is adjustable for a wide range of nozzle sizes. Its trajectory is reasonably low, though it does wet low limbs of nearby trees. A 20° nozzle is also available, but it throws too high for undertree use.

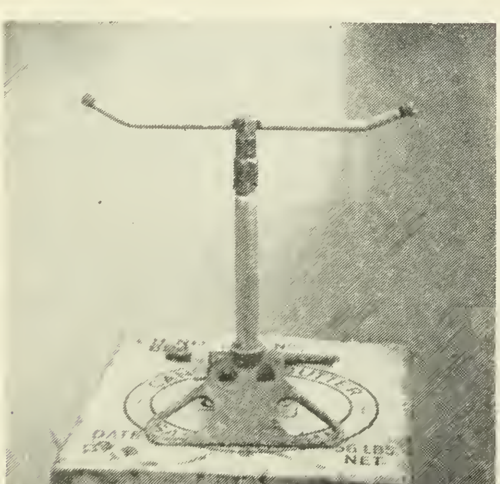

Figure 30. A Buckner sprinkler, on a commercial lawn-sprinkler stand.

(2) *Browning 50* (Figure 21) and *Browning 6.* The Browning 6 is a heavier edition of the Browning 50; otherwise, they are very similar. In each case, the head is turned by the action of the water on a small wheel. They are adjustable for size of nozzle, rate of turning, and distance of throw. They throw with quite a low trajectory. In these tests, an attempt was made to adjust to the greatest distance of throw that would give reasonably uniform distribution of water.

(3) *Buckner 7M71* (Figure 30). This is a whirling two-arm type, with two $\frac{1}{8}$-inch nozzles. It is adjustable for angle of throw and rate of turning, by the simple expedients of bending the arms and turning

[2] The method used and the results obtained in this investigation will be reported more fully in a technical paper.

the nozzles. With the sprinklers used, the arms were flattened down a bit in order to lower the trajectory (Figure 7). To obtain a lower rate of water delivery, one nozzle can be capped.

(4) *Butterfly* sprinklers (Figure 22). These did not prove as satisfactory as the above three, but are included here because they are now in common use in British Columbia orchards. There are several makes of them on the market, some of them un-named. Although they vary in certain respects, they all have the butterfly or harp-like top, beneath which the water stream hits a rotating deflector. They throw their spray rather high in the air, and apply too much water close to the sprinkler (Figure 8).

The uniformity coefficients for the Rainbird 20LA, Browning 50, Browning 6, Buckner 7M71, and a typical butterfly sprinkler are presented in Table 5 in the Appendix. Some of the conclusions of this investigation are as follows: (1) Pressures above 30 pounds should not ordinarily be used. At high pressures, the spray is thrown too high in the air and is blown aside by the wind. This was especially true with the butterfly sprinklers. Also, under orchard conditions, wear of the sprinklers is greater at high pressures. (2) At pressures of 10 pounds or less, distribution of water was very poor in all cases. (3) The uniformity of distribution was increased as the pressure was increased. This was especially true at the wider spacings. (4) An increase in nozzle size had little effect on the area wetted, though the amount of water delivered to this area was increased. The larger nozzles usually gave more uniform distribution of the water at the wider spacings than did the smaller nozzles. (5) As the spacing was increased the uniformity of distribution decreased. (6) With the same area of ground covered in each case, square spacing tended to give greater uniformity of distribution than did rectangular spacing. This was especially true with areas of 800 square feet or more. (7) At the closer spacings, all of the sprinklers listed distributed the water reasonably uniformly. At the wider spacings, the Rainbird gave the greatest uniformity.

As a result of this investigation, suggestions for suitable sprinkler-nozzle-pressure combinations are presented in Table 6 in the Appendix. These suggestions are based on the following assumptions: (1) It is desirable to have as uniform a distribution of the water as is feasible. The water distribution charts indicate that a unformity coefficient of at least 70 is desirable. (2) Because of a high trajectory, greater deflection by the wind, and greater wear of the sprinklers at high pressures, it is usually inadvisable to operate at pressures higher than 30 pounds. (3) Because of the higher trajectory as the pressure is increased, it is preferable to use lower pressures with close spacings. It is assumed that close spacings represent closely planted trees. (4) Because of the adverse effects of wind on uniformity of distribution, it can be assumed that under orchard conditions the uniformity would be less than was obtained in these tests.

In offering the suggestions made in Table 6, it is not meant to imply that these sprinklers are the only ones suitable for undertree use. It is quite possible that other good ones will become available in the near future. It is also possible that better use can be made of some of the sprinklers already tested than was made in this investigation. The Buckner agents, for example, have been able to adjust the Buckner 7M71 in such a manner as to get somewhat wider distribution of water than that noted in Table 5.

In planning a sprinkler system for an orchard, it will not always be found possible to use the exact combinations of nozzle size and pressure that are suggested in Table 6. So far as possible, the pressures used should not be lower than those noted for each nozzle size. Lower pressures are almost certain to cause poorer distribution of the water. In many cases, however, pressures higher than those noted for each nozzle size will prove quite satisfactory; though it may not be advisable to go above a pressure of 30 pounds with certain sprinklers.

Sprinkler Spacing

This subject has been pretty well covered in the section above. It appears that in an open space, the most uniform distribution of water can be obtained with square or nearly square spacing. Under orchard conditions, there is the added factor of tree interference with water distribution. Where the trees are low and bushy, it appears advisable to space the sprinklers such that one is placed in the middle of each tree square. With a portable pipe system, this would mean spacing the sprinklers along the lateral with the same spacing as the trees, and moving the lateral only one tree row at a time. Where the rows are not farther apart than 20 feet, and the limbs are high from the ground, it might be possible to move the lateral two tree rows at a time. When this practice is followed, the lateral should be moved into the alternate rows at the next irrigation.

The question arises as to whether it is advisable always to move the lateral two rows at a time, and then come back in the alternate panels. This appears to be worth while only when the alternate panels have received a reasonably good wetting in the first place. The chief argument for the alternate panel method is that the time between irrigations in any one panel can be lengthened somewhat. Where the wetting is insufficient or patchy, however, the operator should return to each panel just as frequently as when he moves only one panel at a time. Besides, by the alternate panel method he moves his pipes twice as far at each irrigation. Except where the rows are close together and there is little interference with the distribution of the spray, there does not seem to be any advantage in moving two panels at a time.

ESTABLISHING AN UNDERTREE SPRINKLER SCHEDULE

The required delivery capacity of a sprinkler system is dependent in part on the sprinkler schedule; and so also are sprinkler capacity and length of portable pipe. If the water is used full time, less delivery capacity and fewer sprinklers are required than if it is used only part time. And if sprinklers with large nozzles are run for a short time only, fewer sprinklers and less portable pipe are required than if sprinklers with smaller nozzles are run for a longer time. It is therefore difficult to separate the planning of the sprinkling system from the planning of the sprinkler schedule. In the following discussion, the two will be considered together.

Most fruit growers who are now setting up sprinkler systems in their orchards have already had experience with furrow irrigation. They know how much water they need, and how long their orchard will last between irrigations. This makes the problem of establishing a sprinkler schedule much easier. Some growers, however, are either new at the game or they are planting an orchard on virgin soil. Their problem is much more difficult.

Based on experience to date, the following suggestions are offered for a procedure to follow in establishing a schedule for undertree sprinkling:

(1) *Estimate maximum flow of water required per acre.* As already noted under "The Water Supply", a flow of 5 Imperial g.p.m. (gallons per minute) per acre in midsummer appears to be sufficient for general use. With a deep, retentive silt or clay soil, it might safely be reduced to 4 g.p.m., especially in the more northerly districts. With a sandy or shallow soil, it may need to be increased to 6 g.p.m. If the flow is to be intermittent instead of continuous, the capacity of the system will need to be increased accordingly.

Based on a continuous flow for 30 days in each month, 4 g.p.m. will supply 7·6 acre inches per month, 5 g.p.m. 9·5 acre inches, 6 g.p.m. 11·4 acre inches, and 7 g.p.m. 13·3 acre inches (Table 4). Multiplying the maximum number of acre inches required per month by 3 usually gives a rough idea of the total number of acre inches required in the season. This is due to the fact that during part of the season the full capacity is usually not utilized.

Even with new plantings, the delivery capacity should be not less than 4 g.p.m. While the orchard is young, this much water may not be required; but as the trees increase in size and more water is needed, the system will then have sufficient capacity to deliver the amount required.

If a grower knows how much water he needs by the furrow method, he can use this as a guide for a rough estimation of his requirements by the sprinkler method. If he has a deep silt soil, and if he has irrigated carefully by the furrow method, he can not count on saving more than 10 to 15 per cent by the sprinkler method. But if his orchard is planted on a gravel pile that has been receiving sufficient water by the furrow method, he may save 50 per cent or more. It is more than likely, however, that the grower has not had sufficient water to keep his gravel pile properly wetted; which means that he could not count on saving as much as 50 per cent of the water that he had actually used by the furrow method.

2. *Estimate suitable period between irrigations.* This should be done on the basis of water utilization by the trees and cover crop during the heat of the summer. If the grower has made adequate tests of how long the soil moisture will last after a good irrigation by the furrow method, he can rest assured that it will last at least that long by the sprinkler method. In irrigation experiments conducted in the Okanagan Valley, the length of time that furrow irrigation could safely be delayed varied from 7 days on shallow, sandy soils to 30 days or more on deep, heavy soils. It has been common experience, especially with sandy soils, that the time between irrigations can safely be lengthened when a change is made to sprinkler irrigation. However, this cannot be counted on until experience with the orchard under consideration has shown it to be feasible.

Once a grower starts using his sprinkler system, he can soon find out how long his soil moisture actually lasts between irrigations. He can do this with a shovel or auger, examining his soil at say weekly periods after an irrigation with a deep soil, and at shorter periods with a shallow soil. The rate of drying of the soil should be checked following at least three or four irrigations during the first year.

The most satisfactory routine method yet tested here for telling when the soil is getting too dry is as follows: Dig a hole near a tree, 6 to 8 feet from the trunk, to a depth of 15 to 18 inches. Scrape some soil from the side of the lower part of the hole, squeeze it tightly in the hand, and let the soil fall apart again. If the soil holds together in a tight, wet ball there is no hurry to irrigate; but if it tends to fall apart and crumble, it is high time to irrigate. Such tests should be made at various points throughout the orchard.

In most orchard soils, irrigating somewhat more frequently than necessary to prevent wilting does little if any harm; indeed it is preferable to err on the side of too short a period between irrigations rather than too long a period. With more frequent irrigations, however, there are certain possible harmful effects that should be guarded against. In the first place, there is the danger of excessive losses of water and nutrients into the subsoil. In order to obviate this, it may be necessary to lessen the amount of water applied at each irrigation. In the second place, there is the danger of maintaining too high a moisture content in the soil, especially where the soil is deep and heavy. Tree roots require air as well as water, and the only sure way of replenishing the air supply in a heavy soil is to let the soil dry out reasonably well between irrigations.

Many deep silt or clay soils will hold at least a four-weeks' supply of water; and under no circumstances should such soils be sprinkled more frequently than every two weeks.

It should be noted that the safe period between irrigations in July is not necessarily the safe period in May or June. The grower may find it feasible to cut down his flow of water and to extend the period between irrigations during the cooler part of the summer. When planning an irrigation system, however, calculations should be based on maximum requirements—that is, the requirements during the heat of the summer.[3]

3. *Estimate required depth of water at each irrigation.* This can be done quite easily when the maximum rate of flow and the minimum period between irrigations have been determined. For example, if a flow sufficient for 8 inches of water per month is required, and the time between irrigations is 21 days, then about 6 inches of water would be applied at each irrigation. If a flow sufficient for 12 inches per month is required, and the soil needs an irrigation every 7 or 8 days, then about 3 inches would be applied at each irrigation.

4. *Estimate rate of water delivery by each sprinkler;* and 5. *Estimate number of hours to run each time.* These two steps cannot always be separated from one another.

In estimating the rate of delivery of the water by each sprinkler, it is necessary to know the size of sprinkler nozzle to be used and to have some idea of the pressure that will be available. The pressure finally obtained may not be exactly the same as that planned, but the pressure planned can at least serve as a basis for calculation. With these figures, the rate of delivery by the sprinkler head can be estimated from Table 2 in the Appendix. The most desirable pressure for undertree sprinklers is usually between 20 and 30 pounds.

As already noted above, a small nozzle is preferable with a clay soil, and may also be preferable with a sandy soil in certain cases. If the water is applied rapidly to a shallow sand, it may be necessary to change the sprinklers every 3 or 4 hours. If this suits the operator, he will be able to use a minimum of sprinklers and of pipe. Most growers, however, prefer to change their water every 24 or every 12 hours; or at least not any oftener than every 8 hours.

It can thus be seen that every case needs to be considered separately. Following are three examples:

(*a*) The trees are planted 20 x 20 feet apart, are low and bushy, and the grower feels that he should use a small nozzle and a low pressure, so as not to wet the trees too much. The soil is a sandy loam, and the safe time between irrigations is about 14 days. The sprinklers are to be spaced 20 x 20 feet. The rate of water flow available is 5 g.p.m. per acre, giving 9·5 inches of water per month with continuous flow. With an irrigation every 14 days, this means about 4·2 inches at each application. From Table 6, it will be seen that a $\frac{1}{8}$-inch nozzle gives good water distribution at 20 pounds pressure. From Table 2 the theoretical discharge of each sprinkler is found to be 1·74 g.p.m. Using this combination, about 0·5 inch of water would be applied per hour (see Table 3), requiring 8·4 hours of irrigating to apply 4·2 inches. The schedule would be more workable with a $7\frac{1}{2}$ hour irrigation every 12 or 13 days, allowing $\frac{1}{2}$ hour for moving. The number of sprinklers required per acre would be $5/1{\cdot}74 = 2{\cdot}9$, and the length of portable pipe per acre would be $2{\cdot}9 \times 29 = 58$ feet.

(*b*) The trees are planted 30 x 30 feet apart, and the soil is a deep clay loam that can safely be left for 30 days between irrigations. The sprinklers are to be spaced 30 x 30 feet. The rate of water flow available is 4 g.p.m. per acre, giving a monthly application of about 7·6 inches (Table 4). The grower wants

[3] For a more complete discussion of the length of time between irrigations, the reader is referred to Dominion Department of Agriculture Publication 779, "Orchard Irrigation in British Columbia."

to irrigate for 23 hours, allowing 1 hour for moving, and to get around every three to four weeks. Since this soil is heavy, he should apply his water slowly. A $\frac{1}{8}$-inch nozzle, operating at 30 pounds pressure, will deliver 2·1 g.p.m. (Table 2) and apply about 0·27 inches per hour (Table 3) or about 6·2 inches in 23 hours. To apply 7·6 inches in 30 days, this would mean getting around every 24 or 25 days. The number of sprinklers required per acre would be 4/2·1 = 1·9, and the length of portable pipe per acre would be 30 x 1·9 = 57 feet.

(*c*) The trees are 25 x 25 and the soil is light and shallow. An irrigation is needed every 10 days. The grower has a private supply of water and proposes to irrigate for only 12 hours each day, with a flow of 12 g.p.m. This gives 11·4 inches of water per month, or 3·8 inches per irrigation (Table 4). The sprinklers are to be spaced 25 x 25 feet apart. In this case he can use a larger nozzle than he otherwise would, and move his portable pipes more frequently. He would like to move every 4 hours. He will have an extra lateral line, so no time will be lost in moving. The rate of application will thus be 3·8/4 = 0·95 inch per hour. This will require a sprinkler that delivers about 5 g.p.m. (Table 3). Since the trees are fairly close together, it is better to use a large nozzle than a high pressure. A suitable combination appears to be a 13/64-inch nozzle at about 24 pounds pressure, or better still a 7/32-inch nozzle at about 18 pounds pressure (Table 2). With the system being used only half time, the number of sprinklers required will be 6/5 = 1·2 per acre, and the length of portable pipe will be 1·2 x 25 = 30 feet per acre. In addition, there will be the sprinklers and pipe required for the extra line of portable pipe.

Once the new sprinkler system is in actual use, the required length of each irrigation should be checked with a shovel or auger. Periodically during the course of an irrigation, the operator can stop the water and determine how far down in the soil the moisture has spread. Owing to the variability in water distribution from each sprinkler, the soil should be examined at various points around it. As soon as the soil is properly wetted to a depth of four or five feet, the sprinklers can be moved. These tests should be made during at least three or four irrigations the first season.

As one of the advantages of the sprinkler system, it was noted earlier in this bulletin that the application of water can be better controlled by sprinkling than by the furrow method, and that therefore the seepage losses can be reduced. In order to accomplish this desired result, however, care must be exercised in irrigating. The sprinklers should not be run longer than necessary to wet the soil to a depth of five feet; or to wet the soil down to where it is still wet from previous irrigations, where this depth is above the five-foot level. If care is practised in this regard, seepage losses can be reduced to a minimum.

As noted above under subsection 2, it is desirable to allow a deep heavy soil to dry out somewhat between irrigations. A difficulty is sometimes encountered with the soil in the three- to five-foot level, in that it does not dry out as fast as the soil in the upper three feet. When it comes time to irrigate the upper soil, the lower soil may not always need it. In such a case, wetting a heavy soil thoroughly to a depth of five feet at every irrigation would not allow entrance of sufficient fresh air to the lower depth. Extra care should therefore be taken not to irrigate a heavy soil any longer than necessary to wet it down to where it is already well wetted.

A mistake frequently made is not to sprinkle long enough at each irrigation. Too high a proportion of the water is then lost by evaporation from the soil surface. The soil may never be wetted properly below a depth of two feet, so that the subsoil below that point dries out. The result is that the tree roots are forced into the upper soil and the rest of the soil is wasted.

6. *Fit the sprinkler system into the orchard plan.* In the course of steps 4 and 5, the number of sprinklers and the length of portable pipe required per acre can be determined. From these figures, the total of each required for the

whole orchard can be calculated. When the sprinkler system is mapped out, however, it will no doubt be found that the length of portable pipe as calculated will not fit exactly into the orchard plan. To accomplish this, it may be necessary to increase the length of portable pipe somewhat, and hence also the number of sprinklers. This in turn may increase the total rate of water flow required; or if the rate of flow is set, it may mean having to use sprinklers with smaller nozzles, or having to reduce the pressure. There is thus the possibility of having to change the schedule somewhat to suit the dimensions of the orchard. The hose systems are of course more flexible in this respect than are the portable pipe systems.

The schedule thus adopted should be reasonably well adapted to the type of soil, the water requirements of the trees and cover crops, and the size and shape of the orchard. Experimental work done thus far in southern British Columbia indicates that suitable schedules for the heat of the summer will vary all the way from an application of 2½ to 3 inches every week on a gravel pile to 7 inches every month on a deep silt or clay soil.

COST OF EQUIPMENT

Any costs suggested here are presented merely as a means of illustrating the methods of calculation; and of comparing different sprinkler systems. As a basis for the comparisons, a 10-acre orchard will be used, such as is illustrated in Figures 18 and 23. Omitted from the costs in Cases 1 to 7 will be the pump and motor (if required), the pipe necessary to deliver the water to the edge of the orchard, the smaller items of equipment, and the labour of installation. These vary a great deal from orchard to orchard. The costs actually used as a basis of comparison are an average of those quoted by some of the agencies of sprinkler equipment during the winter of 1946-47.

Case 1. A 10-acre orchard, with a 4-inch main pipe down the centre. To be irrigated with a hose system. The laterals to be 1½ inches in diameter and spaced 100 feet apart, and the hoses to be of ¾-inch diameter and 50 feet long. Only one sprinkler to be placed on each hose. Risers to be placed every 50 feet along each lateral, on extensions that will put them near the tree trunks. The general plan to be similar to that illustrated in Figure 18. Second-hand boiler tubing to be used for the main pipe, and galvanized iron for the lateral pipes. The total rate of water flow to be 50 g.p.m., with 25 sprinklers delivering 2 g.p.m. each.

610 feet of 4-inch main pipe at .60 per foot	$ 366
4200 feet of 1½-inch lateral pipe at .40 per foot	1680
980 feet of 1-inch sublateral pipe at .22 per foot	216
1250 feet of ¾-inch hose at .25 per foot	312
98 standpipes and taps at $2 apiece	196
25 sprinklers at $3.50 apiece	88
25 sprinkler stands at $1.50 apiece	37
Total	$2895
Cost per acre	290

Greatest friction loss in system = about 4·0 pounds pressure.

Case 2. The same as in Case 1, except that the laterals are to be spaced every 120 feet (as illustrated in Figure 14), the hoses are to be 60 feet long, and the standpipes are to be spaced every 60 feet.

600 feet of 4-inch main pipe at .60 per foot	$ 360
3780 feet of 1½-inch lateral pipe at .40 per foot	1512
720 feet of 1-inch sublateral pipe at .22 per foot	158
1500 feet of ¾-inch hose at .25	375
72 standpipes and taps at $2 apiece	144
25 sprinklers at $3.50 apiece	88
25 sprinkler stands at $1.50 apiece	37
Total	$2674
Cost per acre	267

Greatest friction loss = about 3·5 pounds pressure.

It can readily be seen from these figures that when the laterals are spaced farther apart, the system can be installed somewhat more cheaply. If two sprinklers were placed on each hose, the cost would be reduced to $249.

Case 3. The same as in Case 2, except that a high pressure has been obtained by gravity, allowing the use of smaller pipes.

600 feet of 3-inch main pipe at .45 per foot	$ 270
3780 feet of 1-inch lateral pipe at .22 per foot	832
720 feet of 1-inch sublateral pipe at .22 per foot	158
1500 feet of ¾-inch hose at .25 per foot	375
72 standpipes and taps at $2 apiece	144
25 sprinklers at $3.50 apiece	88
25 sprinkler stands at $1.50 apiece	37
Total	$1904
Cost per acre	190

Greatest friction loss = about 18 pounds.

It can thus be seen that a considerable saving in cost can be obtained by using smaller pipes, but that the pressure obtained is thereby greatly reduced.

Case 4. A 10-acre orchard, with a 4-inch main pipe down the centre (as in Cases 1 to 3). To be irrigated by a portable pipe system, with two full laterals and extra lengths for spacing from hydrants. General plan to be as illustrated in Figure 23. Hydrants to be spaced 90 feet apart on main line. Sprinklers to be spaced 30 feet apart on lateral. This should lessen the number of couplers required, and therefore the cost of the portable pipe. The total rate of water flow to be 50 g.p.m., with 23 sprinklers delivering 2·2 g.p.m. each.

630 feet of 4-inch main pipe at .60 per foot	$ 378
720 feet of 2-inch portable pipe, with couplings, at .60 per foot	432
8 hydrants at $14 apiece	112
2 hydrant connections at $4 apiece	8
23 sprinkler heads, valves and risers at $5 apiece	115
Total	$1045
Cost per acre	105

Greatest friction loss = about 3·5 pounds.

Case 5. The same as in Case 4, except that the sprinklers are to be spaced 20 feet apart on the laterals. The total rate of water flow to be 50 g.p.m., with 34 sprinklers each delivering 1·5 g.p.m. Hydrants to be 120 feet apart.

640 feet of 4-inch main pipe at .60 per foot	$ 384
740 feet of 2-inch portable pipe, with couplings, at .70 per foot	518
6 hydrants at $14 apiece	84
2 hydrant connections at $4 apiece	8
34 sprinklers, valves and risers at $5 apiece	170
Total	$1164
Cost per acre	116

Greatest friction loss = about 3·5 pounds.

Spacing the sprinklers closer together and using the same length of lateral line increases the cost somewhat. If proportionately less lateral line could be used, the cost would be reduced.

Case 6. The same as in Case 5, except that only one lateral line is used. The total rate of water flow is still 50 g.p.m., but there are now 17 sprinklers each delivering 3 g.p.m.

640 feet of 4-inch main pipe at .60 per foot	$ 384
370 feet of 2-inch portable pipe, with couplings, at .70 per foot	259
6 hydrants at $14 apiece	84
1 hydrant connection at $4	4
17 sprinklers, valves and risers at $5 apiece	85
Total	$ 816
Cost per acre	82

Greatest friction loss = about 9·0 pounds.

It can thus be seen that using higher capacity sprinklers and proportionately less lateral pipe reduces the cost.

Case 7. The same as in Case 5, except that water is obtainable only one week out of two, at a flow of 100 g.p.m. It is found necessary to use three laterals. There are 51 sprinklers, each delivering about 2 g.p.m.

640 feet of 4-inch main pipe at .60 per foot	$ 384
1110 feet of 2-inch portable pipe, with couplings, at .70 per foot	777
6 hydrants at $14 apiece	84
3 hydrant connections at $4 apiece	12
51 sprinklers and risers at $5 apiece	255
Total	$1512
Cost per acre	151

Greatest friction loss = about 8·5 pounds.

When water is obtainable only part time, the cost per acre of installing the system is thus increased considerably.

From the above examples, it can be seen that the costs need to be calculated separately for each orchard. There is an endless variety of combinations of equipment and prices possible, giving a wide range in costs per acre. At present prices, it can be seen that portable pipe systems can be installed more cheaply than portable hose systems.

In order to give some idea of the calculation of pump and motor costs, one more case will be considered.

Case 8.

(*a*) Water requirement 50 g.p.m.

(*b*) Suction lift=12 feet.

(*c*) Feed pipe 4-inch, 300 feet long.
(Friction per 100 feet 0·2 *see* Table No. 1.)
Equivalent head due to friction 3 x 0·2 x 2·31=13·9 feet.

(*d*) Friction in Distribution System (Case 4 or 5) is 4 pounds.
Equivalent head 4 x 2·31=9·3 feet.

(*e*) Pressure required at nozzle assumed 25 pounds.
Equivalent head 25 x 2·31=57·7 feet.

(*f*) Elevation head—Rise from pump to nozzles.
Assumed head or elevation=30 feet.

(*g*) Total calculated head=129·9 feet.

(*h*) Head allowed for pipe bends, etc., 10 per cent=12 feet.

(*i*) Working Head=134·9 or about 140 feet.

A. Pump Selection (*See* Table No. 7)
Centrifugal Pump $1\frac{1}{2}''$. Suction 64 gal. per min.
Motor required 5 H.P. with 3500 R.P.M.

B. Estimated Cost of Pumping Unit (*See* Table No. 7)
(Estimate only not including installation or electrical connections)

a. Pump as listed above	$140.00
b. Motor	120.00
	$260.00

COVER CROPS AND FERTILIZERS

Experience obtained thus far has shown that cover crops can usually be started more easily under the sprinkler method than under the furrow method. They also grow more luxuriantly when sprinkled, especially if the soil is sandy. This appears to be due in part to the maintenance of better moisture conditions in the soil, and in part to better utilization of the fertilizer applied.

Figure 31. Sweet clover grows too high in the orchard and interferes with orchard operations. Tall-growing cover crops should be mown in midsummer.

A further advantage of the sprinkler method is that the cover crop can be more easily mown. Mowing with furrows present is sometimes rather difficult. The practice of disking in midsummer in order to turn under a cover crop that has grown too high is not recommended, as it tends to invigorate the trees too late in the season. If a tall type of cover crop is grown, therefore, mowing once or twice during the season is recommended (Figure 31). The best way to obviate the necessity of mowing is to grow a low type of cover crop.

Any type of cover crop that grows well by the furrow method of irrigating will also grow well by the sprinker method. For side hills subject to erosion, grass sods are recommended, such as creeping red fescue, Kentucky blue grass or brome grass (Figures 32, 33, 34). A combination of grass sod and sprinkling can practically eliminate surface erosion from orchards. Fescue and blue grass are both low growing, brome grass higher growing. Of the three, brome grass is the easiest to start on sandy soils or eroded sidehills. Grass sods are also recommended for red varieties of apples wherever it is difficult to get good colour on the fruit. For stone fruits, white Dutch clover and ladino clover show good promise (Figure 35). Under furrow irrigation, these two cover crops tend to plug the furrows, but under sprinkler irrigation this difficulty is not encountered. A promising mixture for general use is creeping red fescue and ladino clover, both of which have been found to grow much better when sprinkled than when furrow irrigated. They are both low growing. In order to give them a fair chance, the taller weeds and grasses should be mown for a year or two, after which mowing should seldom be necessary.[4]

The difficulty has already been noted of getting a clay soil to absorb water rapidly enough, and it has been suggested that a slow rate of application of water should be used. It is also desirable to grow a dense cover crop, such as blue grass, ladino clover, or the fescue-ladino mixture. These help the clay to absorb water (*a*) by breaking up the drops, so they do not pack the soil surface, (*b*) by protecting the surface with dead leaves and stalks, (*c*) by preventing surface run-off, and (*d*) by opening up the soil with their roots. This last is perhaps the

[4] The reader is referred to the mimeographed circulars on cover crops and fertilizers, that are issued annually by the Okanagan Plant Nutrition Committee.

Figure 32. Creeping red fescue is a low-growing, sod-forming grass. It does better under sprinkler irrigation than under furrow irrigation. It grows slowly the first year after planting.

Figure 33. Kentucky blue grass is a comparatively low-growing, sod-forming cover crop. It grows slowly the first year after planting, but eventually forms a good sod.

Figure 34. Brome grass is a comparatively high-growing cover crop, especially when well fertilized; hence it needs mowing. It forms rather a heavy sod. It is especially well adapted to sandy hillsides or eroded spots.

Figure 35. White Dutch clover forms a nice low carpet. It grows much better under sprinkler irrigation than under furrow irrigation. Ladino clover is simply a giant type of white Dutch.

most important. The soil pores are so small in a heavy soil that water moves down through them extremely slowly, and the only way the soil can be wetted quickly enough is through root holes, worm holes, and cracks.

If a clay soil has become tamped by heavy implements, so as to form a "clay pan" at 8 to 12 inches below the surface, it may take a little more care than usual to open it up for proper water penetration. The best cover crop yet tested here for such a purpose is alfalfa, the roots of which will usually penetrate a clay pan quite satisfactorily. Whatever cover crop is grown, it is advisable to keep heavy implements off such a soil as much as possible.

Changing from furrow to sprinkler irrigation should make little change in fertilizer requirements. At the present time, the recommendations of the Okanagan Plant Nutrition Committee are as follows: (*a*) Apply sufficient nitrogenous fertilizer to produce an annual terminal growth of 10 inches with apples, pears, prunes and cherries, and 16 to 18 inches with peaches and apricots. The best straight nitrogen fertilizer is ammonium nitrate. (*b*) On sandy soils make occasional applications of phosphate as well. Legume cover crops may also need some phosphate. Nitrogen and phosphate can be applied together as 16-20-0. (*c*) On very light and shallow soils, apply a complete fertilizer, such as 8-10-5, or 16-20-0 plus muriate of potash.

It has been a common experience that when a change has been made from furrow to sprinkler irrigation, the trees and cover crop have grown much more vigorously for a year of two. The cause of this has not been determined. It is suspected to be due partly to better soil moisture conditions, and partly to a previous build-up of fertilizer in the soil, that is carried down to the tree roots by sprinkler irrigation. Whatever the cause, it may be advisable to reduce the rate of fertilizer application for a year or two following the change-over, especially if the trees are already somewhat over-vigorous.

APPENDIX

Table 1.—Friction Losses in Iron Pipe, Expressed as Pounds of Pressure Lost per 100 Feet of Pipe*

Imperial gallons per minute	Size of pipe, in inches									
	½	¾	1	1½	2	3	4	5	6	8
1	1·3	0·3	0·1							
2	4·5	1·1	0·4							
3	9·5	2·6	0·8	0·1						
4	16·4	4·2	1·3	0·2						
5	24·7	6·4	2·0	0·2	0·1					
6	34·6	9·0	2·8	0·3	0·1					
8	58·8	15·1	4·7	0·6	0·2					
10		22·9	7·1	0·9	0·3					
12		32·0	10·0	1·2	0·5					
14		42·6	13·4	1·6	0·6	0·1				
16		54·6	17·2	2·1	0·8	0·1				
18			21·4	2·6	1·0	0·1				
20			26·0	3·2	1·2	0·1				
25			38·6	4·8	1·4	0·2				
30			51·1	6·5	2·2	0·3	0·1			
35				8·9	2·6	0·4	0·1			
40				11·4	3·4	0·5	0·1			
45				14·2	4·2	0·6	0·2			
50				17·2	5·1	0·7	0·2			
60				24·1	7·2	1·0	0·3	0·1		
70				32·0	9·5	1·4	0·4	0·1		
80				41·0	12·2	1·8	0·5	0·1		
90				51·0	15·2	2·2	0·6	0·2		
100					18·5	2·7	0·7	0·2	0·1	
120					25·9	3·8	1·0	0·3	0·1	
140					34·5	5·0	1·3	0·4	0·2	
160					44·2	6·4	1·7	0·6	0·2	
180					58·7	8·0	2·1	0·7	0·3	
200						9·7	2·6	0·9	0·4	0·1
250						14·7	3·9	1·3	0·5	0·1
300						20·6	5·5	1·8	0·7	0·2
350						27·4	7·3	2·4	1·0	0·3
400						35·1	9·4	3·1	1·3	0·3
450						43·5	11·7	3·9	1·6	0·4
500						53·0	14·2	4·7	1·9	0·5

*This table is based on Williams, and Hazen's formula, with C = 100. To change loss in pounds pressure to loss in feet of head, multiply the figures by 2·31. The figures for rubber hose are usually somewhat higher than those for iron pipe, while for aluminum pipe they are usually about 2/3 of the figures given in this table. For lateral lines of aluminum or galvanized iron that have sprinklers spaced along them, the figures in this table can be multiplied by 0·3.

Table 2.—Theoretical Discharge of Sprinkler Nozzles.

Nozzle diameter in inches	Discharge, in Imperial gallons per minute, at the following pressures:								
	10 pounds	15 pounds	20 pounds	25 pounds	30 pounds	35 pounds	40 pounds	50 pounds	60 pounds
3/32	0·69	0·85	0·98	1·09	1·20	1·29	1·39	1·54	1·69
7/64	0·94	1·16	1·33	1·49	1·63	1·76	1·89	2·10	2·30
1/8	1·24	1·51	1·74	1·94	2·12	2·30	2·46	2·75	3·01
9/64	1·56	1·91	2·20	2·46	2·70	2·91	3·12	3·48	3·81
5/32	1·92	2·35	2·72	3·05	3·33	3·60	3·85	4·31	4·71
11/64	2·32	2·85	3·29	3·68	4·02	4·36	4·66	5·21	5·70
3/16	2·77	3·40	3·91	4·38	4·80	5·18	5·54	6·20	6·78
13/64	3·25	4·00	4·60	5·14	5·63	6·08	6·50	7·26	7·96
7/32	3·76	4·62	5·32	5·97	6·54	7·06	7·54	8·43	9·24
15/64	4·32	5·30	6·12	6·84	7·50	8·10	8·65	9·68	10·60
1/4	4·92	6·04	6·96	7·79	8·53	9·20	9·85	11·01	12·06
9/32	6·24	7·64	8·80	9·86	10·79	11·66	12·46	13·93	15·26
5/16	7·70	9·43	10·91	12·16	13·33	14·40	15·39	17·20	18·83
11/32	9·30	11·41	13·16	14·71	16·12	17·40	18·62	20·81	22·81
3/8	11·08	13·57	15·66	18·24	19·20	20·72	22·16	24·78	27·14

Table 3.—Depths of Water Application at Different Sprinkler Spacings

Sprinkler discharge in g.p.m.*	Inches applied per hour with spacings as follows:									
	15x15	20x20	25x25	30x30	35x35	40x40	20x15	20x30	20x40	20x50
1.....	0·51	0·28	0·18	0·13	0·09	0·07	0·38	0·19	0·14	0·11
1·5...	0·77	0·43	0·28	0·19	0·14	0·11	0·58	0·29	0·22	0·17
2.....	1·03	0·58	0·37	0·26	0·19	0·14	0·77	0·38	0·29	0·23
2·5...	1·28	0·77	0·46	0·32	0·24	0·18	0·96	0·48	0·36	0·29
3.....	1·53	0·86	0·55	0·38	0·28	0·22	1·15	0·57	0·43	0·34
4.....	2·05	1·15	0·73	0·51	0·38	0·29	1·54	0·77	0·58	0·46
5.....	2·56	1·44	0·92	0·64	0·47	0·36	1·92	0·96	0·72	0·58
6.....	3·07	1·72	1·10	0·77	0·56	0·43	2·30	1·15	0·86	0·69
7.....	3·59	2·02	1·29	0·90	0·66	0·50	2·69	1·34	1·01	0·81
8.....	4·09	2·30	1·47	1·02	0·75	0·58	3·07	1·53	1·15	0·92
9.....	4·61	2·59	1·66	1·15	0·85	0·65	3·46	1·73	1·30	1·04
10.....	5·12	2·88	1·84	1·28	0·94	0·72	3·83	1·92	1·44	1·15

*G.p.m.=Imperial gallons per minute.

Table 4.—Relation Between Rate of Water Flow per Acre and Depth of Application per Month

Rate of flow in g.p.m.* per acre	Depth of application in inches per month, with delivery schedules as follows				
	Continuous	2/3 time†	½ time	1/3 time	¼ time
3·0..........	5·7	3·8			
3·5..........	6·7	4·4			
4·0..........	7·6	5·1	3·8		
4·5..........	8·6	5·7	4·3		
5·0..........	9·5	6·4	4·8		
5·5..........	10·5	7·0	5·2		
6·0..........	11·4	7·6	5·7	3·8	
6·5..........	12·4	8·3	6·2	4·1	
7·0..........	13·3	8·9	6·7	4·4	
7·5..........	14·3	9·5	7·1	4·8	
8·0..........	15·2	10·2	7·6	5·1	3·8
8·5..........	....	10·8	8·1	5·4	4·0
9·0..........	....	11·4	8·6	5·7	4·3
9·5..........	....	12·1	9·0	6·0	4·5
10·0..........	....	12·7	9·5	6·3	4·8
11·0..........	....	14·0	10·5	7·0	5·2
12·0..........	....	15·2	11·4	7·6	5·7
13·0..........	....	....	12·4	8·2	6·2
14·0..........	....	....	13·3	8·9	6·7
15·0..........	....	....	14·3	9·5	7·1
16·0..........	....	....	15·2	10·2	7·6
17·0..........	....	....	....	10·8	8·1
18·0..........	....	....	....	11·4	8·6
19·0..........	....	....	....	12·1	9·0
20·0..........	....	....	....	12·7	9·5

*G.p.m.=Imperial gallons per minute.
† ⅔ time= 2 weeks out of 3, or 16 hours per day.
½ time = 1 week out of 2, or 12 hours per day.
⅓ time = 1 week out of 3, or 8 hours per day.
¼ time = 1 week out of 4, or 6 hours per day.

Table 5.—Uniformity Coefficients

Type of sprinkler	Size of nozzle	Pressure in pounds	Diameter of circle	Uniformity coefficients at the following sprinkler spacings: 20x20	25x25	30x30	40x40	20x30	20x40	20x50	20x60
Rainbird 20LA (7°)......	7/64	15	43	53	58	40	‡	45			
		20	48	67	63	57	24	54	40		
		30	54	82	73	67	31	74	62	40	
		45	58	88	83	86	66	84	78	59	47
		60	64	85	86	82	72	71	78	60	39
	1/8	10	39	48	36	25	......	44			
		15	45	66	61	58	29	48	45		
		20	52	75	67	73	46	69	62	42	
		30	59	78	80	77	64	78	68	57	36
		45	66	83	84	79	78	86	81	72	52
		60	74	86	82	79	70	90	81	82	68
	5/32	10	32	62	17	10	......	38			
		15	41	63	69	50	26	58	45		
		20	44	78	70	67	45	63	58	35	
		30	52	84	89	76	60	86	74	58	
		45	60	88	89	81	75	84	82	68	47
		60	66	88	92	86	72	87	84	79	57
	3/16	10	34	66	26	42	......	61			
		15	40	78	69	66	46	77	64		
		20	46	85	71	73	59	70	74	47	
		30	54	87	85	75	69	80	75	68	39
		45	64	87	87	83	80	89	77	82	65
		60	70	88	91	83	79	87	82	80	69
Browning 50.............	1/8	10	24*	46	11	......	......	5			
		15	32	67	41	52	......	54			
		20	37	74	73	67	......	73	40		
		30	44	87	84	76	51	86	55		
		45	56	89	88	79	73	91	83	56	
		60	61	93	90	83	80	75	90	72	48
Browning 6..............	3/16	10	31	66	59	35	......	37			
		15	36	72	66	62	......	72	39		
		20	44	79	79	69	35	84	66		
		30	50	85	82	57	48	82	86		
		45	58	92	83	78	73	82	86	64	40
		60	65	95	82	82	70	89	77	52	31
Buckner 7M71...........	$\frac{1}{8}+\frac{1}{8}$	10	30†	57	37	15	......	29			
		15	36	62	49	58	......	60	28		
		20	44	86	72	71	......	78	47		
		30	47	84	81	68	45	88	60	33	
		45	46	91	89	82	45	88	57	34	
		60	45	88	93	70	37	83	51	26	
Butterfly (unknown make).	....	15	36	64	55	37	......	54	24		
		20	39	69	66	43	......	59	33		
		30	45	66	56	32	......	51	26		
		45	46	79	65	42	......	59	33		
		60	44	77	56	25	......	49	20		

* The Browning sprinklers were adjusted to throw about as far as possible and still give good distribution.

† With the arms of the Buckner sprinkler flattened down a bit, it did not throw quite as far as it otherwise would.

‡ Before calculations of the uniformity coefficients were made, the charts were examined; and in most cases where the distribution was very poor, calculations were not made. The omission of a uniformity coefficient from this table can therefore be taken as evidence of very low uniformity.

Table 6.—Minimum Pressure Suggestions for Different Sprinkler Spacings

Spacing	Type of Sprinklers		
	Rainbird 20LA	Browning 50 Browning 6	Browning 52 Buckner 7M71
20 x 20	7/64—25 lb. 1/8 —20 lb. 5/32—20 lb. 3/16—15 lb.	1/8 —20 lb. 3/16—15 lb.	1/8+1/8—20 lb.
25 x 25	7/64—30 lb. 1/8 —25 lb. 5/32—20 lb. 3/16—20 lb.	1/8 —25 lb. 3/16—20 lb.	1/8+1/8—20 lb.
30 x 30	7/64—NR* 1/8 —30 lb. 5/32—25 lb. 3/16—20 lb.	1/8 —30 lb. 3/16—25 lb.	1/8+1/8—25 lb.
40 x 40	7/64—NR 1/8 —NR 5/32—NR 3/16—30 lb.	1/8 —NR 3/16—NR	1/8+1/8—NR
20 x 30	7/64—30 lb. 1/8 —25 lb. 5/32—25 lb. 3/16—20 lb.	1/8 —25 lb. 3/16—20 lb.	1/8+1/8—20 lb.
20 x 40	7/64—NR 1/8 —30 lb. 5/32—30 lb. 3/16—25 lb.	1/8 —NR 3/16—30 lb.	1/8+1/8—30 lb.
20 x 50	7/64—NR 1/8 —NR 5/32—NR 3/16—30 lb.	1/8 —NR 3/16—NR	1/8+1/8—NR
20 x 60	7/64—NR 1/8 —NR 5/32—NR 3/16—NR	1/8 —NR 3/16—NR	1/8+1/8—NR

*NR—not recommended.

Table 7.—Guide to Pump Sizes

For complete details of pump sizes,
Refer to Manufacturers

Type of Pump	Suction pipe Inches	Discharge pipe Inches	Max. lift or head Feet	Pump speed strokes Per Min.	Motor R.P.M.	Tank	Well Pumps—Lift in Ft					
							Discharge—40 Lb. Press.					
							20′	HP	50′	HP	100′	HP
									Capacity in Imperial			
Piston— Bore stroke...........	¾	¾	23	....	1725	Yes	4·1	1/6				
	1	¾	23	....	1725	Yes	5·6	1/4				
	1¼	1	23	....	1725	Yes	8·3	½				
	1¼	1	23	....	1725	Yes	13·0	1				
	1¼	1¼	23	....	1725	Yes	....	....	....	....	....	....
3″ x 4″.................	2	2	23	....	1725	Yes	....	....	....	....	....	....
4″ x 5″.................	2	2	23	60	1725	Yes	....	....	....	....	....	....
6″ x 6″.................	3	3	23	40	1725	Yes	....	....	....	....	....	....
Centrifugal (E)				RPM								
	¾-1	....	160	1725	1725	No	....	....	....	....	....	....
	1½	....	180	1725	1725	No	....	....	....	....	....	....
	1½	....	180	1725	1725	No	....	....	....	....	....	....
	1½	....	180	1725	1725	No	....	....	....	....	....	....
	2	....	180	1725	1725	No	....	....	....	....	....	....
	2½	....	180	1725	1725	No	....	....	....	....	....	....
	4	....	180	1725	1725	No	....	....	....	....	....	....
Ejector—Motor driven only.												
	1¼	¾	24	1725	1725	....	9·0	¼	Single	pipe		
	2		24	1725	1725	....	11·0	¼	Single	pipe		
	2	2	24	1725	1725	....	25·0	1	Single	pipe		
	2	2	24	1725	1725	....	52·0	2	Single	pipe		
											Twin pipe	
	¾	1	70	1725	1725	....	....	....	5·6	½		
	1¼	1½	120	1725	1725	....	....	....	11	¾	5	¾
	1½	2	120	1725	1725	....	....	....	8	1	7	1
	2	2½	120	1725	1725	....	....	....	22	2	13	2
	2	2½	120	1725	1725	....	42	3	37	3	18	3
	2½	2½	120	1725	1725	....	114	10	90	10	57	10
	1¼	1½	150	1725	1725	....	....	....	8	1	6·6	1
	2	3	150	1725	1725	....	....	....	16	2	8·5	2

And Power Requirements. (A)

characteristics and Other Types
or Distributors of Pumps

General Service Pumps—Total Head in Feet and Pounds (B)

20′	HP	40′	HP	80′	HP	100′	HP	140′	HP	180′	HP	231′	HP (c)	—
Gallons Per Minute														Approx. cost Pump only.
......	......	7	1/3	......	......	7	1/2	7	3/4	......	......	7	1	
......	......	14	1/2	......	......	14	1	14	1½	......	......	14	2	$150
	......	32	1	......	......	32	2	32	3	......	......	32	5	250
59	1½—	59	2	59	3	59	4	59	6	59	7	59	9	380
16	1/4	16	3/4	16	3	16 D	1½	......	......	......	......	......	......	$ 70
40	1/2	40	1	40	2	40 D	3	40 D	5	40 D	7½	......	......	
64	3/4	64	1½	64	5	......	......	......	......	......	......	......	......	
......	......	......	......	64 D	3	64 D	3	64 D	5	64 D	7½	......	......	140
80	3/4	80	1½	80	5	80 D	5	80 D	7½	80 D	10	......	......	160
160	3	160	5	160	7½	160	7½	160 D	10	160 D	15	......	......	
......	......	......	......	320	15	......	......	......	......	......	......	......	......	210

Single impeller	(A) Compiled by Agricultural Engineering Office Central Experimental Farm, Ottawa.	Approx. Cost Motor only
"	(B) Total Head—for pumps with power as shown.	
"	In calculating the total head for any installation include suction lift, pipe friction loss, and nozzle pressure required.	
"	One pound pressure equal to 2·34 feet of head.	1 HP $ 55
"	(C) Horse Power—based on 60 cycle alternating current.	3 HP 85
"	(D) Based on double speed 3500 RPM motor.	5 HP 120
Triple impeller	(E) Belt drive centrifugal pumps are available in sizes similar to motor-drive pumps	7½ HP 140
"	for speeds up to about 1800 R.P.M. and a head of about 120 feet.	10 HP 160

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